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Understanding Physical Activity, Motor Competence and Obesity in Preschool Children

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By

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For Ruth

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List of Abbreviations

ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
BIA	Bioelectrical impedance analysis
BMI	Body mass index
BOTMP	Bruininks-Oseretsky test of motor proficiency
DEXA	Dual-energy X-ray absorptiometry
EYFS	Early years foundation stage framework
FMS	Fundamental movement skills
HW	Healthy weight
KG	Kilograms
KTK	Körperkoordinationstest für Kinder
LC	Locomotor motor competence
LPA	Light physical activity
M-ABC	Movement assessment battery for children
MC	Motor competence
MD	Motor development
METS	Metabolic equivalent units
MMT	Maastrichtse Motoriek test
MOT 4-6	Motoriktest für vier- bis sechsjährige Kinder
MPA	Moderate physical activity
MVPA	Moderate-to-vigorous physical activity
n	Sample size
NCMP	National child measurement programme
OC	Object-control motor competence
OW	Overweight
PA	Physical activity
PDMS	Peabody developmental motor scales
Perceived LC	Perceived locomotor motor competence
Perceived MC	Perceived motor competence
Perceived OC	Perceived object-control motor competence
PL	Physical literacy
PSMC	The pictorial scale of perceived movement skills competence for young children
PSPCSA	Pictorial scale of perceived movement skill competence
PSPP	Physical self-perception profile
SD	Standard deviation
SPA	Sedentary physical activity
SPSS	Statistical package for social sciences
TGMD-2	Test of gross motor development-2nd edition
TPA	Total physical activity
VPA	Vigorous physical activity
WHO	World Health Organisation
β	Beta coefficient

Abstract

Introduction: Globally, prevalence of overweight preschool aged children has increased (De Onis, et al., 2010) and is a serious public health concern (Public Health England, 2017). Both motor competence (MC) and physical activity (PA) are important for healthy weight status in young children (Stodden, et al., 2008; Robinson, et al., 2015) and should be important in managing overweight and obesity risks. The preschool ages represent a critical period of life for promoting PA and engaging in MC activities (LeGear, et al., 2012; Timmons, et al., 2012).

Aims: The overall aims of this thesis were to provide original contributions regarding PA, MC and weight status associations in British preschool aged children, as described by Stodden and colleagues (2008) conceptual model. Each of the three experimental studies had differing aims. Study One examined associations between PA, MC and weight status, and to establish current PA levels. Study Two investigated the mediating capabilities of perceived MC on relationships between PA and MC. Study Three tracked children a year later to examine which past or present variables contributed to current PA, MC or BMI.

Methods: Following institutional ethics approval, 177 children and their parents from childcare provisions within Coventry and Warwickshire were recruited. Objective measures of PA (accelerometers), actual MC (TGMD-2, Ulrich, 2000), perceived MC (PSMC, Barnett, et al., 2015) and BMI were obtained. PA was categorised as total PA (TPA) or moderate-to-vigorous PA (MVPA). MC was reported as total MC or separated into locomotor MC (LC) and object-control MC (OC). Children were assessed at baseline for Study One and a year following at follow-up for Study Two and Three.

Results: During Study One, associations were found between PA and MC (TPA and overall MC, TPA and OC, MVPA and overall MC, and MVPA and OC). In Study Two, there were no mediating impacts of perceived MC on the relationship between PA and actual MC. During Study Three, previous BMI and current MVPA were identified as the better predictors of current BMI. 96.4% of variance (*P* = 0.001) in each child's follow-up BMI were explained by baseline

BMI *(P* = 0.001) and follow-up MVPA *(P* = 0.003); 49.8% of variance in follow-up TPA *(P* = 0.007) were explained by baseline MVPA *(P* = 0.011), TPA (*P* = 0.012) and BMI *(P* = 0.006); 65.0% of variance in each child's follow-up MVPA *(P* = 0.001) were explained by baseline and follow-up BMI *(P* = 0.003; *P* = 0.002), baseline MVPA *(P* = 0.003), and baseline TPA *(P* = 0.003); 27.5% of variance *(P* = 0.051) of each child's follow-up LC was explained by follow-up BMI *(P* = 0.008), follow-up TPA *(P* = 0.037) and follow-up MVPA *(P* = 0.032).

Conclusion: Good MC is an important correlate of children meeting PA guidelines for health when using population and age validated PA cut-points. Relationships between actual MC and PA is not mediated by perceived MC in a small sample of British preschool childhood. MVPA is the most consistent variable to maintaining healthy weight status in British preschool children.

Thesis Map

	Aims
Study One: Relationships between motor competence, physical activity and obesity in British preschool aged children	• To investigate associations between weight status, physical activity and motor competence, as proposed by the Stodden, et al., (2008) model. • To identify current physical activity levels and compliance to physical activity recommendations.
Study Two: Does perception of motor competence mediate associations between motor competence and physical activity preschool children?	• To examine if associations between physical activity and actual motor competence in British preschool children are mediated by perceived motor competence, as suggested in the Stodden, et al., (2008) model.
Study Three: Moderate-to-vigorous physical activity is more important than motor competence in maintaining healthy weight status in British preschool children.	• To identify the strongest contributor to current BMI, from previous BMI, and previous and current physical activity and motor competence. • To identify the strongest contributor to current physical activity, from previous physical activity, and previous and current BMI and motor competence. • To identify the strongest contributor to current motor competence, from previous motor competence, and previous and current BMI and physical activity.

1 Introduction

1.1 Obesity

Childhood obesity is a serious public health concern in the UK (Public Health England, 2017). Evidence currently suggests that prevalence of obesity has maintained high levels in recent years (Lissner, et al., 2010; Rokholm, et al., 2010), specifically in the UK (Boddy, et al., 2010). Recent figures show that almost a third of British children are classified as overweight or obese (National Health Service, 2018) and younger generations of British children are becoming obese earlier and remaining obese longer (Johnson, et al., 2015). Children who are overweight at 5-years of age are four times more likely to be obese at 14 years (Cunningham, et al., 2014) and it is estimated that 92 million preschool aged children are at risk of being overweight in the future (De Onis, et al., 2010). Obesity and being overweight are conditions in which an individual has a particularly high quantity of body fat (National Health Service, 2018). To define overweight adults, body mass index ≥25 kg/m2 is used, and to establish obese adults, body mass index ≥30 kg/m2 is used (National Health Service, 2018). To define obesity and overweight children, body mass index cut points are influenced by age and sex (Cole, et al., 2000), but international cut points have been established and are widely used (Cole, et al., 2000). Therefore, cut-points to identify overweight and obesity in children change depending on age and stage of development.

Recommended strategies to reduce obesity have focused on healthier diets and physical activity (PA). Engaging in PA is one suggested way to reduce obesity (Hills, et al., 2011) and may hold potential as part of the solution for the ongoing obesity epidemic (Wiklund, 2016). It is probable that reduced PA and increasingly sedentary behaviours are important contributing factors (Epstein, et al., 2000; Department of Health, 2018), so understanding components of PA may be beneficial in understanding is role in obesity and inactivity (Stodden, et al., 2008).

1.2 Physical Activity

PA encompasses any type of bodily movement produced by skeletal muscles which results in energy expenditure (Caspersen, et al., 1985), and considered a collective of exercise and any other activities involving bodily movement. The terms ‘PA’ and ‘exercise’ are used interchangeably despite being different constructs (Casperson, et al., 1985), as exercise is a subgroup of PA, which is planned, structured and regular, with the aim of improving or maintaining one or more components of fitness (Public Health England, 2016).

As a multi-dimensional behaviour, PA is categorised and measured using types, frequencies, duration and intensities (Valanou, et al., 2006). Type of PA refers to activity behaviours, examples including walking, sitting, and standing. Duration and frequency are measured in time and spells of PA. Intensities of PA are distinguished by effort exertion or rate of energy expenditure (Department of Health, 2018). PA intensities are measured on a continuum: sedentary (SPA), light (LPA), moderate (MPA) and vigorous PA (VPA; Batacan, et al., 2016). PA intensity separation is expressed as metabolic equivalent units (METS) based on rates of energy expenditure (Ridley, et al., 2009). MET values are based on multiples of resting metabolic rates which are either estimated or measured directly (Ridley, et al., 2009). Establishing resting metabolic rate is complicated in children, and varies between children depending on age, sex, body mass and pubertal status (Ridley, et al., 2009).

In children, LPA is categorised as ‘easy’ activities, such as slow walking, MPA is any activity that slightly elevates the heart rate, like brisk walking (Cavill, et al., 2006), VPA are activities that elevate the heart rate significantly, including running (Freedson, et al., 1998; Hendelman, et al., 2000). Sedentary behaviour (or SPA) is argued to be entirely different from PA (Pate, et al., 2011) as SPA is not solely the absence of LPA, MPA or VPA but involves activities that involve little to no movement, such as sitting and lying down (Pate, et al., 2008). A recent definition states that SPA is any waking activity that involves energy expenditure ≤1.5 METS when undertaken in a seated or reclined position (Tremblay, et al., 2017).

Preschool aged children's PA, between 3-to-6-years, is typically characterised by intermittent patterns of long periods of low activity intensity mixed with short bursts of high intensity activity (Barbosa and de Oliveira, 2016), with active play, being the most common type of activity reported (Department of Health, 2018). Lower moderate-to-vigorous PA (MVPA) during the early years has associations with increased adiposity (Janz, et al., 2009). Additionally, levels of MVPA are inversely associated with measures of central body fat in 3-to-8-year old children (Martinez-Gomez, et al., 2011). Health and fitness of young people suggests that low levels of PA associated with increased rates of obesity (Hills, et al., 2011; Mountjoy, et al., 2011; Bray, et al., 2016). Higher levels of habitual PA during the early years has been identified to be protective against obesity (Moore, et al., 2003; Jiménez-Pavon, et al., 2010) and sustained PA as children age assists with weight management (Kwon, et al., 2015).

Engaging in PA has more benefits than just adiposity reductions, which will be discussed in detail in the Literature Review (Page 15). Such benefits include cardiovascular disease prevention (Bürgi, et al., 2011; Ekelund, et al., 2012; Timmons, et al., 2012), improved bone health (Tobias, et al., 2007; Janz, et al., 2010; Baptista, et al., 2012; Timmons, et al., 2012) motor competence development (Hardy, et al., 2010; Bürgi, et al., 2011; Timmons, et al., 2012; Laukkanen, et al., 2014), cognitive function (Hillman, et al., 2011; Syväoja, et al., 2014), muscle development (Timmons, et al., 2012), psychosocial health (Timmons, et al., 2012) and deceased morbidity and delayed mortality (Andersen, et al., 2006). Dose-response relationships are observed between PA and health, indicating the higher dose of PA the increased benefits obtained (LeBlanc and Janssen, 2010; Füssenich, et al., 2016). PA is important for a variety of health benefits, beyond overweight and obesity, which deserve attention.

The proportion of British children engaging in regular PA, decreases as children age (National Health Service, 2018). In adults who do not participate in sufficient PA, many will attribute this to a negative experience or poor enjoyment of PA in childhood (Beni, et al., 2017). Increases in sedentary lifestyles may be the causes to declines in PA (Biddle, et al., 1998; Strong, et al., 2005; Inyang, et al., 2015). Being more sedentary may be due to safety concerns, restricting PA engagement opportunities, and advancing technology such a television viewing, (Biddle, et al., 1998; Strong, et al., 2005; Inyang, et al., 2015).

The UK Government published a plan to tackle childhood obesity, (Department of Health, 2018) consisting of one particular strategy to encourage all children to enjoy participating in ≥60 minutes of PA each day by improving the quality of sport and PA in schools and supporting early years settings, which if successful, may increase habitual PA in this age group. Current estimations of British preschoolers complying with ≥60-minutes of MVPA are reported to be as low as 9% in males and 10% in females (National Health Service, 2018). Newly updated guidance on the PA recommendations (Department of Health, 2019) recommends that children engage in skills which considered to be the building blocks of PA (Gallahue and Donnelly, 2007), motor competence (MC) skills like jumping, throwing, catching and skipping. Better proficiency in MC has been shown to be a correlate of PA (Slykerman, et al., 2016). Therefore, the promotion of PA in the early years is critical to slow age-related PA declines.

1.3 Motor Competence

1.3.1 Actual Motor Competence

MC is a generic term used to describe goal-directed proficiency in movement-based activities (Robinson, et al., 2015). MC is comprised of fundamental movement skills (FMS) which are a group of observable organised basic movement patterns of two or more body segments (Gallahue and Donnelly, 2007) and are the building blocks for more complex and refined movements (Goldfield, et al., 2012; Foweather, et al., 2015). Such skills are comprised of locomotor, like running and hopping, and object-control skills such as catching and throwing. If these basics skills are not established, larger and more specific sports-based skills will be hindered (Gallahue, et al., 2011). Sufficient MC is a prerequisite for successfully functioning in daily life or for participation in sport and physical activities requiring more advanced movement skills (Cools, et al., 2009). In order to be sufficiently competent in these skills, children require opportunities to practice and perfect these skills within supportive and stimulating environments (Goldfield, et al., 2012). MC is regarded as one aspect of physical literacy (PL). An individual with good PL is regarded as motivated, confident, physically competent, knowledgeable and understanding, to value and take responsibility for engagement in PA for life (Whitehead, 2019).

The UK Government produced guidelines for children's physical development as part of the Early Years Foundation Stage Statuary Framework (EYFS; Department for Education, 2017), which childcare provisions use as part of the early years' curriculum. The EYFS includes three prime areas of learning applicable to children from birth to the year each child turns 5-years-old, that are age and stage relevant. One prime area of learning is Physical Development, which is separated further, into two sections: 'Moving and Handling' and 'Health and Self-Care'. Included in 'Moving and Handling' are several MC based skills, such as running, jumping, hopping, sliding, catching, throwing and kicking. The EYFS Statuary Framework provides examples to improve children's MC and ways to track physical development. As a prime area of learning, in early years children, British children should be sufficiently proficient in MC.

With regards to health outcomes, MC has been identified to have an inverse relationship with weight status (Barnett, et al., 2008; Lubans, et al., 2010; Morgan, et al., 2013), which will be discussed in more detail in the upcoming Literature Review (page 15). In a cross-sectional study, with a range of participants that were children, adolescents and adults identified that those with low MC had significantly compromised musculoskeletal fitness compared to those with high MC (Cantell, et al., 2008). Additionally, MC was a significant predictor of BMI at all age groups, suggesting that individuals with low MC with have compromised health-related fitness (Cantell, et al., 2008). Also, in adolescents MC was associated with aerobic fitness, muscle strength, muscle endurance, flexibility and body composition, which are all considered as important health-related constructs (Hands, et al., 2009). Following a review, Cattuzzo, et al., (2016) found strong evidence of associations between MC with body weight status, cardiorespiratory fitness and musculoskeletal fitness, but uncertain conclusions of MC and the association with flexibility.

But it must be noted that MC has more benefits than just weight status, as evidence suggest in preschool aged children, that those with low MC engage with lower social participation and higher frequency of social reticence, compared to higher motor competent children (Bar-Haim and Bart, 2006). Having greater MC, has an increased likelihood to engage in activities to engage with peers and as a consequence develop friendships (Smith, 2003). Following intervention in preschoolers, children with higher MC were more likely to report gender-integrated friendships post-intervention and identify that they have more friends (Mulvey, et al., 2019). Additionally, greater MC has associations with greater academic performance and social and emotional adjustments to school environments (Bart, et al., 2007) and associations with better academic attainment among teenagers (Jaakkola, et al., 2015). Additionally, enhanced previous MC predicts future cognition after two-year follow-up in males (Haapala, et al., 2019). So, whilst MC may have health benefits, there are also social and mental health benefits that can be derived from good MC proficiency.

Children's PA is thought to be influenced by MC which will in turn influence weight status (Stodden, et al., 2008; Robinson, et al., 2015; Barnett, et al., 2016a). Being sufficiently competent in MC is an important determinant of PA through a bi-directional relationship that strengthens as children age (Barnett, et al., 2008). Cross-sectional evidence suggests that there are positive associations between MC and PA in preschool aged children (Fisher, et al., 2005; Cliff, et al., 2009; Bürgi, et al., 2011; Iivonen, et al., 2013; Foweather, et al., 2015). Preschoolers' (aged 3-years) previous volume of MVPA has shown predictive capabilities of 5-year old locomotor MC (LC, Barnett, et al., 2016a).

1.3.1.1 <u>Motor Development</u>

Motor development (MD) is the study of lifespan change in motor behaviour (Roberton, 1989) and consists of various milestones each healthy child will go through but may develop at varying rates (Holbrook and Keonig, 2000). Initial stages of MD are extensions of the upper spine as a foetus between 5-to-6-weeks of pregnancy (Malina, et al., 2004). When born, MD is influenced by maturation characteristics, including morphological, physiological and neuromuscular, and the environment as children age; which when combined determine each child's motor repertoire. Malina, et al., (2004) suggests that five categories interact to contribute to MD (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). The strength of interaction between these variables will result in individual differences in MD, which in turn with alter individual's MC.

During infant and toddler stages of life (<2-years) postural, locomotor and prehensile control is developed. McGraw (1975) explains the development of phylogenetic motor behaviours (e.g. sitting up, standing and walking) are required for normal functioning and are less affected by practice; whereas ontogenetic skills (e.g. catching, throwing, kicking), require practice and are the building blocks for sporting activities and PA. Newell (1986) describes MD as emerging within a dynamic system, from the interactions between the individual, the environment and the task they are trying to complete. MD may be variable due to personal characteristics, motivation, prior experience and the community and cultural values of the individual (Gallahue, et al., 2011). Differences in how these are developed may occur in differences between the individual's structure and function, environment and task (Newell, 1986), but several MD theories agree that normally developing children progress through each MD step successively.

The Sequential Model of MD describes four stages of development: "reflexes-reactions"; "FMS"; "transitional motor skills"; "sports-specific skills" (Seefeldt, 1980). Reflexes and reactions are present from birth as a protective mechanism. FMS are previously discussed as basic movement skills. This model proposes a proficiency barrier after the FMS stage, as without basic MC in FMS development of advanced skills may be too complex for an individual to learn. Progression into the transitional motor skills and sports-specific skills stages requires surpassing the proficiency barrier; suggesting individuals with a higher level of MD skills may be the key to participation in a wider array of games, sport and PA.

The Mountain Model of MD (Clark and Metcalfe, 2002; Clark, 2005) suggests that motor skill development is not a linear process, as the Sequential Model suggests, and that experiences and constraints will influence progression through the model. The Mountain Model of MD consists of five stages: “reflexive”; “preadapted”; “FMS”; “context-specific”; and “skilful”. Reflexive and preadapted stages describe the period from, birth to initial stages of self-care, when a child can self-feed and move independently. Again, failure to efficiently develop FMS will make other context-specific skills difficult to learn, resulting in fewer opportunities to engage in PA (Clark, 2005). Context-specific skills are skills that only occur in certain activities, for example netball shot, basketball dribble, rugby punt. The final stage is the skilful stage. Each of the various ‘peaks’ of the mountain correspond with progression of one skill. This model appreciates that an individual may be highly skilful in one aspect of MD, such as a footballer being able the kick a ball accurately with their dominant foot; however, when throwing a pass, which is seen in basketball, or any other non-specific football skill, MD will be low and therefore have low ‘peaks’, and addresses MD as a comprehensive development, rather than just one area becoming more significantly developed than others.

The Hourglass Model of MD (Gallahue, et al., 2011) suggests that variances between individuals’ MD is from genetics and environmental differences, and involves “reflexive moment phase”; “rudimentary movement phase”; “FMS phase”; “specialised movement phase”, to provide lifelong MC. The model suggests that the reflexive and rudimentary phases are fixed and occur in the same order for all children, however at the FMS stage, variance in MD can be observed. The more skills attained, the increased chance an individual will have to engage in PA endeavours throughout life. When considering this in conjunction with Newell’s (1986) constraints theory, variance in MD occurs in the FMS stage, resulting from the individual’s stature, and body build, or their function, motivations to attention.

1.3.2 Perceived Motor Competence

Perceived MC is the way an individual will interpret their own performance of MC skills (Harter, 1978). Perceived MC may be an important aspect to consider when enhancing a child's PA and MC, and ultimately weight status. In children, perceived MC has been shown to be misaligned to actual MC, but as age increases, this misalignment declines (Noordstar, et al., 2016; Washburn and Kolen, 2018). Inaccuracies between actual and perceived MC may occur from limited cognitive abilities in younger ages, accuracy improves as children age, effectively, that young children may confuse effort with skill proficiency (Stodden, et al., 2008). Children who believe they are proficient in MC skills will be more likely to enjoy and sustain interest in PA than those who are less skilled (Stodden, et al., 2008). Low perceived MC has implications for feelings and motivations for PA (Harter, 2003).

Elevated perception of MC capabilities has been associated with increased PA in children as children that believe they move well, find PA more enjoyable and therefore will elect to be more physically active (Carroll and Loumidis, 2001; Barnett, et al., 2008; Khodaverdi, et al., 2016). Perceived MC has correlations with PA (Biddle, et al., 2005; Babic, et al., 2014; Khodaverdi, et al., 2016) and with actual MC (Lubans, et al., 2010; LeGear, et al., 2012; Noordstar, et al., 2016; Lopes, et al., 2018). Additionally, high perceived MC is correlated to higher levels of fitness and lower incidence of overweight and obesity (Ulrich, 1987; Crocker, et al., 2000; Okely, et al., 2001; Okely, et al., 2004; Welk and Ekelund, 2005; Wrotniak, et al., 2006) and previous literature indicates evidence of a positive relationships between motivation and perceived competence (Roberts, et al., 1981; Valentini, et al., 2004; Ihsan, et al., 2015). Evidence suggests that confidence and motivation is significantly increased in children that are categorised as highly active compared to children in low activity groups which will maintain higher perceived MC (Behan, et al., 2018). So, it can be suggested that by maintaining higher self-perceptions, children's motivation and confidence will also remain high, which will have benefits on self-esteem, perceived MC, actual MC and PA (Behan, et al., 2018).

Stodden and colleagues (2008) suggest that perceived MC mediates the associations between PA and actual MC, and this mediation strengthens as children age. Perceived MC has been shown to mediate associations between actual OC and PA in adolescents (Barnett, et al., 2009). There is a paucity of studies incorporating the mediating capabilities of perceived MC, compared to those that have examined actual MC, particularly in the early years. But perceived MC is worthy of further investigation as perception of MC is important in its own right as children that perceived they are sufficiently proficient in MC and PA are more inclined to engage in MC and PA (Stodden, et al., 2008).

1.4 Early Years Age Group

The preschool years are considered a critical period for establishing healthy lifestyle behaviours (Reilly, et al., 2008; Timmons, et al., 2012) and has been identified as an opportune time for the development of MC skills (Foweather, et al., 2015), especially considering 20% of children are already at risk of being overweight or obese by the time they enter school (Birch and Ventura, 2009). It is believed that in the first five years of life, children learn more physical skills than any other time point (British Heart Foundation, 2012) as by age 5-years, brain size is approximately 90% of adult size (Dekaban and Sadowsky, 1978). Thus, such behaviours need to be developed in early childhood.

Large proportions of children spend vast quantities of time within nursery environments which may not be appropriately structured to encourage PA engagement and MC development, but it is important to understand the relationships between these variables in British preschoolers before such alterations could be made.

Currently, the UK provides 30 hours of funded childcare for all children after the third birthday regardless of socioeconomic status, ethnicity, or other differences (Department of Education, 2017). It is expected that 90% of children in the UK access this provision and attend a childcare environment (Department of Education, 2017). Children in these childcare settings, attend for usually large periods each day (Ward, et al., 2010). Therefore, there is large potential to access large groups of young children, before detrimental behaviour is learnt and established. Childcare settings (centre-based care and preschools) have been identified as a promising setting for the delivery of interventions to increase PA among children during early childhood (Finn, et al., 2002; Dowda, et al., 2009; Trost, et al., 2010).

This thesis shall aim to provide original and novel contributions to the literature regarding associations between PA, MC and obesity in British preschool aged children, which has yet to be explored with objective measures of PA, MC and weight status.

2 Literature Review

In order to understand the relationships between physical activity (PA), motor competence (MC) and weight status it is important to review previous literature exploring associations between these variables. This chapter will provide an overview of literature to ascertain inconsistencies, which will later be addressed by this thesis.

2.1 Obesity

The prevalence of individuals considered overweight is a public health burden, especially considering obesity and hypokinetic conditions (Allender, et al., 2007) and paediatric obesity is associated with increased risk of cardio-metabolic illness in later life (Freedman, et al., 2007). Economic obesity costs the UK Government £27 billion per year and £6.1 billion specifically to the National Health Service (Public Health England, 2017), and costs to obese individuals is a reduction in life expectancy between 8-to-10-years (Stewart, et al., 2009).

The international rise in obesity began in the 1970s, initially developing in high-income countries, however many middle and low-income countries have now joined the obesity pandemic (Sassi, et al., 2009). In England, the National Child Measurement Programme (NCMP; National Health Service, 2018) assesses BMI in reception class (4-to-5-years) and year 6 (10-to-11-years). The prevalence of overweight and obese children in year 6 increased between 2013/14 and 2017/18, increasing from 14.4% overweight and 19.0% obese to 14.4% and 20.1% respectively. In 2013/14, 13.1% of reception children were considered overweight and 9.4% were considered obese, compared to 12.8% and 9.4% in 2017/18 (National Health Service, 2018). Prevalence of overweight and obese children is something that must be addressed to limit and eliminate the economic, individual and national costs.

2.1.1 Obesity and Health

Obesity related morbidities are more frequently reported in adulthood, but there are numerous health consequences associated with high body fat in the earlier years of life, and risk of poor health continue into adulthood (Hills, et al., 2011). Such concerns include fatty liver disease, glucose intolerance, insulin resistance (Patrick and Nicklas, 2005), Type II diabetes mellitus, cardiovascular disease, hypertension, high cholesterol, sleep apnoea, (Niehoff, 2009) skin conditions, menstrual abnormalities, cancer, poor balance and orthopaedic problems (Eckel, et al., 2011) and increases the risk of subsequent asthma (Story, 2007).

2.1.1.1 Longitudinal changes in Obesity

Childhood obesity has been shown to track into adulthood (Whitaker, et al., 1997; Simmonds, et al., 2016) with approximately 55% of obesity in children tracks into adolescents, 80% of obese adolescents will be obese in adulthood, and around 70% of those will be obese over 30-years-old worldwide (Simmonds, et al., 2016). Overweight children are 6.5 times more likely to be overweight in adulthood comparted to healthy weight peers, as moderate to strong tracking tendencies are present in relation to BMI (Herman, et al., 2009).

During early childhood, as age increases so does BMI until after infancy when BMI falls before continuing to rise, referred to as the “adiposity rebound” (Rolland-Cachera, et al., 1984). Earlier adiposity rebound is associated with increased risks of obesity and may be important in determining later health (Rolland-Cachera, et al., 1984; 2006). Adiposity rebound is not a critical point for intervention, but the periods around this may be important to understand the early mechanisms for obesity development (Rolland-Cachera and Cole, 2019). Early adiposity rebound, before age 5-years, is predictive of adult obesity (Ip, et al., 2017), and weight at age 5-years is a good predictor for further health of the individual (Gardner, et al., 2009), therefore suggesting that early childhood health is important in obesity prevention.

2.1.1.2 Concerns for overweight children

Compared to children who are healthy, health-quality of severely obese children and adolescents is much lower and similar quality of life as those diagnosed with cancer (Schwimmer, et al., 2003). Hao and colleagues (2018) identified longitudinal associations between childhood BMI trajectory patterns and subclinical cardiovascular risk in young adulthood. Childhood obesity has serious long-term implications on health in later life (Niehoff, 2009).

Psychological correlates with childhood obesity are concerning, as associations with anxiety, depression, isolation, withdrawal, hyperactivity, conduct problems, low self-esteem, peer conflicts and interaction problems have been highlighted (Csabi, et al., 2000; Pine, et al., 2001; Lamertz, et al., 2002; Lumeng, et al., 2003; Vila, et al., 2004; Lawlor, et al., 2005; Jansen, et al., 2008; Reeves, et al., 2008; Roth, et al., 2008; Drukker, et al., 2009; Pitrou, et al., 2010; Sahoo, et al., 2015). Overweight children have been shown to have associations with more pronounced behavioural problems, compared to healthy weight children (Carey, et al., 1989; Hasler, et al., 2005; Lumeng, et al., 2003). Depression has predictive values for the development of overweight and obesity in children and adolescents (Goodman and Whitaker, 2002; Hasler, et al., 2005). Obesity in childhood is a precursor to adulthood depression (Sanchez-Villegas, et al., 2010).

Weight gain and psychological problems may have impacts on each other, namely, psychological disorders may foster weight gain and weight gain may lead to psychological problems (Vila, et al., 2004; Lawlor, et al., 2005), particularly depression which is both a cause and consequence of obesity (Goldfield, et al., 2010). Therefore, childhood obesity has detrimental impacts of psychological wellbeing, and following a review of current literature

Martin, and colleagues (2016) highlights that British male preschoolers at age 5-years performed scientifically lower in pattern construction, when obese at 3-years-old, compared to those of a healthy weight *(P* = 0.01), and female preschoolers that were obese at age 3-years, had significantly lower performance in naming vocabulary *(P* = 0.02) and pattern construction *(P* = 0.01) at aged 5-years, compared to females with healthy weight. Martin, et al., (2016) concludes that stronger relations between obesity and cognition and educational attainment emerge in later childhood, meaning it is important to tackle obesity in earlier ages to prevent cognitive development delays.

Further implications include discrimination against obese individuals in children as young as 2-years-old (Budd and Hayman, 2008) and social marginalisation (American Association of Paediatrics, 2014). Childhood obesity has been negatively associated with school performance, overweight and obese children are four times more likely to report problems at school than healthy weight peers (Schwimmer, et al., 2003). Overweight children are more likely to have lower school attendance, especially those with chronic health concerns, such as asthma and diabetes (Sahoo, et al., 2015), contributing to lower academic performance.

2.1.2 Determinants of Obesity

The ecological paradigm to understand over fatness and obesity, suggests three main influences on equilibrium levels of body fat; biological, behavioural and environmental, which are mediated through energy intake or energy expenditure, and moderated by physiological adjustments during periods of energy imbalance (Egger and Swinburn, 1997). Biological influence may include age, sex, hormonal factors and genetics; behavioural influences include factors like habits, emotions, attitudes, beliefs and cognitions developed through learning; and environmental influences may include parental influences, policies, and design of the current living environment.

Obesity is a complex problem with many contributing factors, including, behaviour, environment, genetics and culture. However, in the simplest form, obesity is caused by an energy imbalance between energy intake through food and energy output through physical activity. The causes of obesity go beyond a simplistic view of energy balance, and are complex and multifaceted (Gortmaker, et al., 2011). Anderson and Butcher, (2006) have found that no single factor has led to increases in children's obesity, but a variety of factors have simultaneously contributed to increased energy intake and decreased energy output.

Literature has documented the change in dietary pattern to include higher energy dense diet, with higher fat content, particularly saturated fats, greater added sugars, increases in animal consumption, reduced ingestion of complex carbohydrates and dietary fibre, and reduced intake of fruits and vegetables

(Chan and Woo, 2010). Several studies have reported in children that higher intake of calories, sugar, sugared beverages and fat intake in children leads to obesity (Kuhl, et al., 2012; Laster, et al., 2013; Petroy, et al., 2017). Poor nutrition is also a contributory factor to increasing risk of overweight and obesity (Sahoo, et al., 2015; Lanigan, et al., 2010; Shepard, 2009). Additionally, obese preschoolers were less likely to have fresh vegetables available at home compared to healthy weight preschoolers (Boles, et al., 2013).

Parental influence is has also shown to change weight status in children. Parents with overweight children are often less concerned about their children's weight status than expected. Lampard, et al., (2009) reports 82% of parents of overweight and 18% of parents of obese Australian children reported little parental concern, aged between 6-to-13-years. In the UK, 42% of parents with an obese 5-year-old reported to be unconcerned about their child's weight (Brophy, et al., 2009). This is concerning, as parents have been shown to be significantly influential on their children's weight status, including maternal pregnancy smoking status, gestational weight gain and parental weight gain in infancy all increase likelihood of weight gain in off-spring (Whitaker, 2004). Furthermore, children born to overweight mothers were more likely to be overweight or obese in later childhood, in addition to children who were breastfed longer had reduced risk of obesity (Kitsantas & Gaffney, 2010). However, it is not just maternal factors that influence weight status in children, paternal variables also gave been shown to influence off springs' BMI, diet quality, and PA (Vollmer, et al., 2015).

2.1.3 <u>Obesity, Socioeconomic Status and Ethnicity</u>

Ethnicity and socioeconomic status are social categories that capture differential exposure to conditions that may have health consequences. Both categories are linked, but each may have isolated impacts to health (Williams and Collins, 2016). British preschoolers at age 5-years, with low socioeconomic status have increased risk of obesity and poor health (Brophy, et al., 2009). Obesity was associated with lower income levels and lower education levels of the parents in British 5-year-old children, with overweight Black children being twice as likely to live in low-income families with limited or no maternal qualifications (Brophy, et al., 2009).

The risks of ill-health are disproportionately high in some racial and ethnic groups, including Black (Hajat, et al., 2004; Barnett, et al., 2006; Brophy, et al., 2009; Zilanawala, et al., 2015; Toselli, et al., 2016), South-East Asian (Barnett, et al., 2006; Sproston and Mindell, 2006), and Chinese populations (Hajat, et al., 2004; Razak, et al., 2007). Regarding preschoolers, ethnic minorities are more likely to have poorer health that Caucasian children (Toselli, et al., 2015; Zilanawala, et al., 2015). Zilanawala, et al., (2015) demonstrates in British preschoolers, Black Caribbean and Black African children were more likely to be obese and overweight, and Pakistani children had the lowest odds to be obese. Brophy, et al., (2009) identifies that Black children have a risk ratio of obesity 2.5 times that of Caucasian children. Children from lower socioeconomic status and non-caucasian backgrounds are more likely to be classified as overweight.

2.2 Physical Activity

Physical activity (PA) declines as children age (Basterfield, et al., 2011; Kalman, et al., 2015; Mann, et al., 2018). Current British PA recommendations are dependent on age and stage of the individual (Department of Health, 2018) and are devised for positive health outcomes when sufficiently active. Children under the age of 5-years, who are not yet walking, PA should be encouraged, and sedentary time should be minimised. Children under the age of 5-years, but are capable of walking, should be physically active in any intensity for at least 180-minutes per day, including light, moderate and vigorous PA (TPA), and should minimise time spent being sedentary. For children aged between 5-to-18-years, current recommendations are to complete 60-minutes of moderate-to-vigorous PA (MVPA) everyday, including activities that strengthen muscle and bone at least three days per week and minimise sedentary activity. For adults, between 19-to-65-years, guidelines are to be active every day, achieve 150-minutes of moderate intensity PA over the week or 75-minutes of vigorous intensity PA, complete PA to improve muscle strength twice per week, and minimise sedentary time. For adults over 65-years, activity levels are the same as the previous adult recommendations, but also recommend including PA focused on balance and co-ordination at least twice a week.

Other countries recommend different PA participation for children, such as The Department of Health and Children in Ireland (2014) recommends that children between 2-to-18-years should complete at least 60-minutes of MVPA per day, and include muscle and bone strengthening and flexibility exercises three times a week. America (Office of Disease Prevention and Health Promotion, 2018), Canada (CSEP, 2017) and Australia (The Department of Health, Australia, 2019), agree that in the early years, a minimum of 60 minutes of MVPA is required. Therefore, in early years children completing ≥60-minutes of MVPA and/or ≥180-minutes of TPA including light, moderate and vigorous PA (LPA, MPA and VPA) is appropriate.

Many countries have PA recommendations; but few countries have quantified sedentary time recommendations in minutes. The British recommendations provide some ideas regarding sedentary time by minimising sedentary time but not quantifying duration. This may be due to limits in understanding of the role sedentary behaviour.

In a large longitudinal study of 32 countries, children's participation in MVPA is low (Kalman, et al., 2015) as male MVPA rates between 2002 to 2010 have significantly increased *(P* ≤ 0.001), from the percentage of children that spent ≥60-minutes in MVPA increasing from 21.4% to 23.4%; and females' MVPA compliance has increased between 2002 and 2010 from 12.9% to 13.9% *(P* ≤ 0.01). England and Ireland's MVPA compliance demonstrated small declines in males (28.9% to 28.6%; 35.4% to 34.3%) and females (15.6% to 14.6%; 21.7% to 20.3%). Scotland's MVPA compliance significantly declined in males (25.2% to 18.3%) and females (13.6% to 11.0%). Wales' MVPA compliance minimally increased between 2002 and 2010 in males (21.8% to 24.2%) and in females (11.9% to 13.8%).

Internationally, volume of MVPA is inconclusive, and has been reported to be as low as 18.8 minutes in males and 15.7 minutes in female American preschoolers (Ostbye, et al., 2013), compared to 82 minutes in males and 86 minutes in female Swedish 2-year-olds (Johansson, et al., 2015). Similarly, quantity of TPA is ambiguous and varies from highs of 345 minutes in males and 353 minutes in females (Johansson, et al., 2015) and as low as 133.85 minutes (Vale, et al., 2010). Conclusions drawn by Johansson, et al., (2015) would suggest that Swedish children are sufficiently active, but Kalman, et al., (2015) suggest that only 15.5% of males and 12.2% of females comply with MVPA recommendations. Vale, et al., (2010) reports that Portuguese preschoolers are sufficiently active regarding MVPA, but insufficiently active regarding TPA recommendations. TPA was collated as 133.85 minutes for all children, 143.45 minutes in males and 121.05 minutes in females, and that 66.75%, 74.95% and 55.7% of all, male and female children completed TPA recommendations. With regards to MVPA, all, male and females obtained 95.35, 103.3 and 84.85 minutes, and 89%, 79.45% and 85.55% complied with MVPA recommendations. Portuguese MVPA compliance was the highest reported in this cohort of studies, however, older children's MVPA compliance is vastly different (males: 18.4%; females: 8.5%; Kalman, et al., 2015).

Recent findings suggest that only 9% of British males and 10% of British females aged 2-to-4-years meet national TPA guidelines (National Health Service, 2018), and only 28% of 5-to-7-year olds met national MVPA guidelines. Er, et al., (2018) reports low compliance rates of 11.4% for TPA (143.55 minutes) and 0% for MVPA (22.23 minutes). O'Dwyer, et al., (2013) reports TPA as 112.7 and 115.95 minutes for males and females; MVPA as 42.75 and 41.45 minutes in males and females. In a parallel study, O'Dwyer, et al., (2014) also found that MVPA was inadequate, as males obtained 43.85 minutes, and females obtained 36.4 minutes of MVPA per day. One study that identified that children's MVPA was almost high enough and TPA was compliant with recommendations, reporting that MVPA was 51.4 minutes and TPA was 293.4 minutes per day (Collings, et al., 2017). However, Collings, et al., (2013) identifies that children are sufficiently active with TPA as high as 517.6 and 500.8 minutes and MVPA as high as 89.0 and 82.3 minutes between sex-groups. Correspondingly, Hesketh, et al., (2015) reports that all children (100%) complied with both TPA and MVPA recommendations, with an average of 506.6 minutes of TPA and

215.6 minutes of MVPA. Consequently, establishing current PA patterns in the UK early years and preschool populations is difficult. Globally, children are considered to not be sufficiently active.

It must be recognised that comparison of the aforementioned studies is limited as although Kalman, et al., (2015) tracked children's MVPA longitudinally, to measure MVPA engagement, a self-reported questionnaire describing MVPA as "any activity that increases heart rate and makes you get out of breath for some time", which may cause bias depending on the individuals' current physical fitness. Additionally, children's self-perceptions of their own PA levels may be inaccurate, as ~50% of children estimate their PA levels incorrectly (Corder, et al., 2010). Furthermore, Kalman, and colleagues investigated older populations (11-to-15-years), which have limited comparability to preschoolers. However, large international comparisons of PA are limited, so Kalman, et al.,'s (2015) study could show the potential directions in future PA. Although MVPA appears to be increasing, it is very difficult to feel positively, as even with the highest compliance rate of 35.4%, nearly two thirds of children are not being sufficiently active worldwide, (Kalman, et al., 2015). It is important to recognise geographical changes in PA compliance as a plethora of studies regarding PA are from international populations and may have limited applicability in the UK. Even with adjoining countries, the percentages of children complying with ≥60-minutes of MVPA per day are vastly different, Ireland's MVPA compliance in 2010 for males and females is almost double Scotland's (Kalman, et al., 2015).

Further comparison between countries regarding PA behaviours, is 'The Active Healthy Kids Global Alliance Report Cards', provided to 38 countries from 6 continents, graded from A = excellent, to F = failing (Trembley, et al., 2016). Common indicators were used to inform the grading system, consisting of "overall PA levels", "organised sport participation", "active play", "active transportation", "sedentary behaviour", "family and peers", "community and built environments", and "government strategies and investments". Tremblay, et al., (2016) concludes that most countries would demonstrate proficiency in some areas and then would be poor in others. Average rating was 'C' for all countries, and continent grades were C for Africa, Asia and Europe, with North and South America being graded as D overall. No country is leading or lagging in all components to have a variety of successes and challenges. Average grades for “overall PA levels” and “sedentary behaviours” were regarded as low, grade D. Sixteen countries were graded F on ≥1 component, 30 countries reported ≥1 grade D, but only six countries reported ≥1 grade A. Countries that demonstrated general success overall were Denmark, the Netherlands and Slovenia, all European countries. Slovenia was the highest scoring country to obtain grade A for “overall PA levels”, with the next highest-grade being B-. In the UK, England, Ireland, Scotland and Wales all scored C overall. The highest grades for a British country was B+ for “school” for England and “community and built environment” for Ireland, and lowest results were F for Scotland in “overall PA levels” and “sedentary behaviours”. A grading of C suggests that the country is “succeeding about 40-59% of children and youth” in that component, meaning around half of children may not be sufficiently active through a country’s failings.

2.2.1.1 Physical Activity and Active Play

Obtaining PA through active play is a more likely way young children will engage PA compared to organised PA, as PA in early childhood is sporadic (Barbosa and de Oliveira, 2016). Active play is PA that consists of regular bursts of MVPA within it. The potential to increase PA through active play may be substantial given that is can be engaged in whenever children elect to (Janssen, 2014). Active play is associated with higher habitual PA and MVPA levels (Brockman, et al., 2010; Cooper, et al., 2010; Brussoni, et al., 2015; Gray, et al., 2015; Tremblay, et al., 2016; Frank, et al., 2018) and health outcomes (Johnstone, et al., 2019). Children have been shown to achieve between 30-to-40% of PA recommended MVPA during active play (Ridgers, et al., 2006).

2.2.2 Physical Activity and Weight Status

Childhood obesity is associated with sedentary lifestyles and low engagement in PA (Parsons, et al., 1999; Besson, et al., 2009; Jimenez-Pavon, et al., 2010; Guinhouya, et al., 2011). Previous cross-sectional studies have identified that lower rates of PA are associated with increased risk of obesity in children and adolescents (Jimenez-Pavon, et al., 2010), and PA also contributes to improvements in body composition and assists in weight management (Jakcic, 2009). Results from the Avon Longitudinal Study of Parents and Children (ALSPAC) study in British children, suggest that increasing MVPA by 15-minutes is associated with lower risk of obesity by 50% in males and 40% in females (Ness, et al., 2007). However, what is not clear is which is the precursor, whether low levels of PA cause excess weight gain or if individuals with high adiposity are less inclined to be physically active.

Higher PA was associated with lower body fat percentages in preschoolers (Bürgi, et al., 2011). In Portuguese preschool children, MVPA was negatively associated with BMI z-score ($P = 0.04$) in males; and females demonstrated negative associations between waist circumference and MVPA among girls in the 90th percentile, with overweight classification beginning at the 85th percentile ($P < 0.05$). Oddly, one study found that time spent in MVPA ($P = 0.036$) and TPA ($P = 0.010$) was positively associated with BMI-z scores, which was attributed, by the authors, to be a consequence of fat-free mass increasing BMI (Er, et al., 2018).

Some research has failed to identify PA associations with weight status. O'Dwyer, et al., (2011) compared PA between overweight and healthy weight British preschool children using uniaxial accelerometery over seven days. There were no significant differences between MVPA between weight status groups, but overweight boys displayed significantly lower moderate PA than their healthy weight counterparts ($P = 0.02$). Collings, et al., (2017) also found no associations between BMI and PA but did find associations between the sum of skinfolds and light PA in British preschoolers ($P = 0.042$). No significant differences were also observed between healthy weight, overweight and obese Finnish preschoolers' MVPA (Matarma, et al., 2017).

Discrepancies surrounding PA levels may be due to measurement error, differing measurement measures, population and age group differences, measurements of PA dimensions, seasonal effects, and changes in PA over time (van Sluijs, et al., 2008). All of such factors may change PA results, measurement measures range from subjective measures like questionnaires to objective measures like pedometery or accelerometery (Reiser and Schlenk, 2009), which can provide different results when compared (Hesketh, et al., 2013; Lau, et al., 2013). Differing populations may also provide differing PA outputs, as PA engagement may change depending on weather (Tucker and Gilliand, 2007), terrain and season (Baranowski, et al., 1993). Therefore, it is important that when comparing literature surrounding PA levels, various assessment methods, differing populations and other external factors such as seasonal effects and local terrain are considered.

2.2.3 Physical Activity and Health

Adequate PA provides fundamental health benefits, as previously highlighted. In addition to physical health benefits PA has impacts of psychological wellbeing, such as easing depressive symptoms, reducing anxiety and improving self-esteem in children (Biddle and Asare, 2011; Field, 2012; Brown, et al., 2013; LeBlanc and Janssen, 2010). Therefore, it can be suggested, that in addition to easing overweight and obesity, PA has more health benefits, and regardless of weight status, children should be encouraged to participate in enough PA for such benefits, from an early age, where positive behaviours can be established.

Positive associations between PA and systolic and diastolic blood pressure (Shea, et al., 1994), musculoskeletal health (Janz, et al., 2001; Aly, et al., 2004; Litmanovitz, et al., 2007), and bone mineral density and health (Janz, et al., 2001) are reported. However, evidence for associations between blood lipids and cholesterol and PA remains inconclusive. Nonetheless, higher PA is linked with improved cognitive development (Fedewa and Ahn, 2011; Carson, et al., 2016) and academic attainment (Hillman, et al., 2008; Howie and Pate, 2012; Singh, et al., 2012; Booth, et al., 2014; Buscemi, et al., 2014). Increasing social competence has also been found when PA engagement increases (Colwell and Lindsey, 2005; Labo and Winsler, 2005). Additionally, regular PA in children and adolescents has inverse associations with depression (Motl, et al., 2004; McMahon, et al., 2017) and positive correlations with self-esteem and emotional well-being (Ahn and Fedewa, 2011; Wood, et al., 2013; Liu, et al., 2015).

However, a large proportion of evidence linking PA and childhood health is cross-sectional in nature.

Childhood PA has been shown to have influences on adulthood health. Low engagement in PA and sedentary behaviours observed in childhood has been associated with poor chronic adulthood health (Saakslahti, et al., 2004; Strong, et al., 2005; Andersen, et al., 2006; Baxter-Jones, et al., 2008; Singh, et al., 2008; Herman, et al., 2009; LeBlanc and Janssen, 2010; Department of Health, 2018; Tremblay, et al., 2011; Field, 2012; Loprinzi, et al., 2012; Rangul, et al., 2012; Bugge, et al., 2013; Knowles, et al., 2013; Trinh, et al., 2013; Bielemann, et al., 2014). Evidence supports positive associations between childhood PA and adulthood health; particularly weight status (Singh, et al., 2008; Herman, et al., 2009; Trinh, et al., 2013), cardio-metabolic health (Rangul, et al., 2012; Bugge, et al., 2013; Knowles, et al., 2013), musculoskeletal health (Baxter-Jones, et al., 2008; Bielemann, et al., 2014) and psychological wellbeing (Rangul, et al., 2012; Hallal, et al., 2015)

2.2.3.1 Dose-Response Relationship of Physical Activity

Dose-response relationships are reported between PA and health benefits (LeBlanc and Janssen, 2010; Füssenich, et al., 2016). Dose-response associations in observational studies in school-aged children indicate that increasing PA, increases health benefits (LeBlanc and Janssen, 2010). Whilst a dose-response relationship is unclear between blood lipids and cholesterol in youth and children (LeBlanc and Janssen, 2010), weak associations have been identified between high blood pressure and PA, overweight and obesity with PA, bone density and PA, and depression and PA (LeBlanc and Janssen, 2010). Additionally, clear, strong associations between metabolic syndrome and PA (LeBlanc and Janssen, 2010). Increasing MVPA is reported to change metabolic scores in children (Metcalf, et al., 2009) and improve cardio-metabolic health in children (Ekelund, et al., 2012; Chaput, et al., 2013). A graded dose-response relationship appears to exist between activity and mortality, with mortality being greatest at the lower end of the activity distribution and lowest at the more active end (Boreham and Riddoch, 2001), especially when considering there is sufficient evidence to indicate that engaging in adequate childhood PA influences adulthood diseases, specifically those in relation to obesity and osteoporosis (Boreham and Riddoch, 2001).

2.2.4 Sex-Differences in Physical Activity

In prepubescent children there should be no observed sex-differences in physical outputs (Malina, et al., 2004) however, individuals with the same chronological age can be markedly different with respect to biological maturity (Thompson, et al., 2003; Rowland, 2005; Baxter-Jones, et al., 2005; Lloyd, et al., 2014). It is accepted that females mature before males, (Malina, et al., 2004; Malina, 2014), therefore sex-differences may relate to earlier biological maturations when using chronological age as a comparative. Some studies suggest that females mature on average 2-years before males (Malina, 1991), other studies have suggested this could be 3-years (Thompson, et al., 2003). Additionally, prior to puberty both sexes possess similar biological characteristics, such as genotype, body composition, strength, and limb lengths (Malina, et al., 2004).

When using step counts to distinguish PA, McIntyre, et al., (2018) reports that Australian males are more active than females at ages 6, and 8-years. Similarly, in Norwegian male preschoolers, males obtained higher TPA, MVPA and step counts than females (Andersen, et al., 2017). Additionally, Bouvin, et al., (2013) and Vale, et al., (2010) report sex-differences, with males being more active than females in TPA and MVPA. Both Bouvin, Vale and colleagues (2010, 2013) assessed PA in a cross-sectional study and may be under representative of habitual PA, so a potential extension of this work would be to conduct longitudinal research to identify other potential causes to identify why males are more active than females.

Correspondingly, British preschoolers have also demonstrated sex-differences in PA. Males are widely reported to engage in more PA than females (Collings, et al., 2013; O’Dwyer, et al., 2014; Foweather, et al., 2015; Hesketh, et al., 2015). Collings, et al., (2013) identified similar sex-differences in accelerometer measured MVPA in preschool children, in a Southern English cohort of 398 children at 4-years *(P* = 0.042), but this was only because of the contribution of MPA *(P* = 0.007), as VPA was insignificant between sex-groups *(P* = 0.48). Congruently, O'Dwyer, et al., (2014) in a North-West urban city of England, 188 children aged between 3-to-5-years were found to have sex-differences in weekday and weekend day MVPA *(P* = 0.001; 0.05). Additionally, Foweather, et al., (2015) identified sex-differences in weekday MPA *(P* = 0.005), VPA *(P* = 0.026), MVPA *(P* = 0.007) and total *(P* = 0.040), and weekend day MPA *(P* = 0.010), VPA *(P* = 0.034) and MVPA *(P* = 0.012). Hesketh, et al., (2015) used PA accelerometery data over a minimum of two days to establish TPA *(P* = 0.02) and MVPA *(P* = 0.004) was significantly in males than females, (202 children; 3-to-4-years). However, measurement of PA over only two days, with no criteria for weekend wear time may not be representative of true PA values. Er, and colleagues (2018) assessed 150 preschoolers' PA and sedentary time. During time in a childcare provision, MVPA *(P* = 0.020), LPA *(P* = 0.040) and TPA *(P* = 0.024) demonstrated significant sex-differences. Similarly, during time outside of a childcare provision MVPA *(P* = 0.037) and TPA *(P* = 0.045) demonstrated significant sex-differences. However, unlike the previously mentioned studies, which all used age validated cut-points for PA intensities, Er, et al., (2018) used PA cut-points validated in older children (Puyau, et al., 2002), namely 6-to-16-year olds, when assessing preschoolers, which may mean that the cut-points may not be sensitive enough to capture changes in PA intensity in a younger population. This may have influenced PA results and may be the cause of any discrepancies.

Conversely, some studies have reported no sex-differences in preschool aged children (Cliff, et al., 2009; Johansson, et al., 2015). In Australian preschoolers (Cliff, et al., 2009), MVPA was found not to be significantly different between males and females *(P* = 0.295). Similarly, Johansson, et al., (2015) found no sex-differences in high PA *(P* = 0.36), low PA *(P* = 0.56), sedentary behaviour *(P* = 0.38) or step counts *(P* = 0.85) when assessing 123 Swedish 2-year old children. However, the cut-points used by Johansson, et al., (2015) do not distinguish between light, moderate or vigorous activities, only between high and low PA (Johansson, et al., 2014) and therefore comparability to other studies is limited.

Moore, et al., (2003) tracked 103 American children (mean age 4.2 ± 0.8 years) over eight years, identifying that more active children had smaller gains in BMI compared to lower active children. The most active children reached adiposity rebound at ~6-years-old, whereas less active children reached this earlier at ~5-years-old. Similarly, to BMI, more physically active children had the greatest benefits referring to body fat, indicating that adiposity rebound occurs later in more active children. With a sex-split, results remained consistent, more active children demonstrated lower gains in body fat over time, however, females (except for those in the highest activity tertile) had greater increases in body fat from 5-years of age compared with males. Moore, et al., (2003) conclude that there are strong protective effects of PA on adiposity in male and female children, however the effect is more evident in highly active females. Trost, et al., (2003) observed sex-differences in PA association strength with BMI in Australian preschool children (3-to-5-years). Overweight males were significantly less active than their non-overweight peers during the preschool days, but this difference was not observed in females. Nonetheless, Rowlands, et al., (2000) found no sex-differences in the strength of associations between PA and adiposity, in Welsh children (mean age 9.5 ± 0.7 years) but confirmed a significant inverse association between PA and adiposity. In British children, declines in MVPA were associated with increases in fat mass index ($P < 0.05$) and increased BMI-z score ($P < 0.05$) in males, but not in females, over two years (Rowlands, et al., 2000). It is evident that it is possible to identify individuals at risk of high adiposity from early ages by identifying children with lower PA.

2.2.5 Determinants of Physical Activity

Using the ecological health approach (Egger and Swinburn, 1997) biology, behaviour and environment may influence PA levels, similarly to obesity. Biological determinants of PA have been identified in children. Several studies have reported that age has a significant negative relationship with PA, as children age, their habitual PA declines (Basterfield, et al., 2011; Basterfield, et al., 2012;

Tammelin, et al., 2014). This is usually attributed to the displacement of PA into more sedentary behaviours, like television viewing (Mutz, et al., 1993).

Parental influences must also be considered because in early childhood, children demonstrate less control over their lifestyle behaviours. It has been reported that parental influence on young children's PA is significant. Preschoolers who received greater parental support to participate in PA or had parents who rated PA as highly enjoyable were significantly more likely to engage in more than one hour of habitual daily PA (Zecevic, et al., 2010; Xu, et al., 2015; Carson, et al., 2016; Lindsay, et al., 2017).

Additionally, British preschoolers have been shown to accumulate more MVPA in childcare environments compared to home environment (Hesketh, et al, 2015), but compared with international suggests that low levels of MVPA are common within childcare environments (Reilly, 2010; Hnatiuk, et al., 2014).

2.2.6 Physical Activity, Ethnicity and Socioeconomic Status

There is some evidence of PA differences between ethnicity groups (Sallis, et al., 1993; Kuepper-Nybelen, et al., 2005; Anderson, et al., 2008; Beets and Foley, 2008; Pate, et al., 2008; Pfeiffer, et al., 2009; Marino, et al., 2012; Chuang, et al., 2013), conversely there are others that found no ethnic influence (O'Dwyer, et al., 2013; Olesen, et al., 2013; Ostbye, et al., 2013). Many of the studies conducted surrounding this topic are from the United States (Sallis, et al., 1993; Anderson, et al., 2008; Beets and Foley, 2008; Pate, et al., 2008; Pfeiffer, et al., 2009; Marino, et al., 2012; Chuang, et al., 2013; Ostbye, et al., 2013) or Europe (Kuepper-Nybelen, et al., 2005; Olesen, et al., 2013), with few from the UK (O'Dwyer, et al., 2013).

Furthermore, there are inconsistencies between which and the strength of such differences. In subjective measures of PA, caucasian early years children have been reported by direct observation to have lower sedentary behaviours than Hispanic (Sallis, et al., 1993; P = 0.017), and Asians through parental questionnaires (Beets and Foley, 2008, P = 0.001), and obtain higher TPA than Hispanic (Sallis, et al., 1993; P = 0.001). Black preschoolers have also been reported to be more physically active with TPA than caucasian and Hispanic populations when using a combined parental and teacher interview (Marino, et al., 2012; *P* = 0.007). When assessing PA by observation, Pate, et al., (2008) suggests that ethnic differences are not apparent in sedentary behaviour (*P* = 0.14), LPA (*P* = 0.35), MVPA (*P* = 0.36) and TPA (*P* = 0.55). In objective methods, using accelerometery, (Pfeiffer, et al., 2009) black preschool aged children had higher MVPA than caucasian children overall (*P* = 0.05) and black males obtained more MVPA than caucasian males and other ethnicities combined (*P* = 0.05).

There are a multitude of factors that may influence differences between PA, such as PA assessment methods, age, gender, obesity, socioeconomic status and ethnicity, which may explain some of the inconsistencies in the literature. Cultural differences in parenting, have been shown to have a main effect on PA parenting practices, specifically by discouraging PA due to safety concerns (O'Connor, et al., 2014), which may explain variances in PA between ethnicities. It has been previously acknowledged that children from ethnic minority groups are more likely to reside in areas of low socioeconomic status (McGarrigle and Kearns, 2009) which may also influence PA.

Socioeconomic status may also have a role in PA and sedentary behaviours. When assessed via direct observation, children's PA was not influenced by socioeconomic status in American children (Sallis, et al., 1993; *P* = 0.84). Similarly, in Mexican preschoolers, low PA was not associated with low socioeconomic status (Fernald, et al., 2008; *P* > 0.05), however, PA was assessed via parental questionnaire, and likely to be overestimated, which may explain no associations (Hesketh, et al., 2013; Lau, et al., 2013). In British children, measured PA via accelerometer, in preschool children (3-to-5-years) and found no ethnic differences in any intensity of PA and sedentary behaviour (Jackson, et al., 2003; O'Dwyer, et al., 2013; *P* > 0.05). In 339 Scottish children (Jackson, et al., 2003), aged 4-to-5-years, PA was assessed via accelerometery and identified that there were only differences in one component of sedentary behaviour. Males that were from deprived socioeconomic backgrounds engaged in lower sedentary behaviour compared to those from affluent socioeconomic status *(P* = 0.01).

Inconsistencies in the literature may represent the difficult nature of capturing accurate PA in children ≤6-years old via accelerometery or objective measures. Additionally, it has been shown in young children, that parents and teachers significantly over estimate children's PA (Lau, et al., 2013). It is estimated that almost 89.7% of mothers of inactive preschool-aged children and 36.6% of all parents perceive their child to be sufficiently active (Hesketh, et al., 2013). Therefore, parental reported PA in any capacity may have limited relevance to true values. Consequently, any differences found from the previous studies may have over- or underestimated the ethnic influence on early years children PA or sedentary behaviours.

2.2.7 Longitudinal Changes in Physical Activity

There is a paucity studies that have tracked children's PA from early childhood into adulthood as this is a difficult investigation to undertake, due to the nature of recording children's PA (Telama, et al., 2014). Several have tracked PA through early childhood (Gabel, et al., 2011; Edwards, et al., 2013; Abbott, et al., 2016). Cross-sectional studies are useful to identify snapshots in time in one population, but longitudinal studies are over several time points which can identify how previous life situations can influence later life, namely if previous PA has an effect on future PA.

In early childhood, PA demonstrates moderate to low tracking over time. Gabel and colleagues (2011) found over a 15-month study that Canadian preschoolers have similar TPA over time, and demonstrated fair tracking (P = 0.05), but MVPA increased between baseline and follow-up (P = 0.03) and exhibited poor tracking (P = 0.28). In a separate Canadian study, preschoolers' PA, at all intensities, also exhibited moderated tracking (P < 0.001). In a slightly longer longitudinal study, 234 American children's PA was observed at age 3-years and again at age 7-years via accelerometery (Edwards, et al., 2013). Between baseline and follow-up children's TPA, LPA and MVPA declined (P = 0.0001; 0.15; 0.0005) and sedentary behaviour increased (P = 0.0001). Overall tracking of PA between age 3-to7-years was poor. However, males that began with high MVPA at age 3-years maintained higher MVPA at ages 4, 5, 6 and 7-

years than those with low or middle tertile MVPA, corresponding with those who began with high sedentary behaviour at 3-years maintained higher sedentary behaviours at 4, 5 and 6 years compared to those in the low and middle tertile groups. In females, if high MVPA was observed at 3-years then this would maintain at ages 4 and 5-years compared to those with middle and low MVPA at 3-years old. Edwards, et al., (2013) suggests that sex-differences in PA patterns occur in early childhood. However, other literature has found that TPA increased from the age of 3-years to 4-years (Jackson, et al., 2003).

In an extensive longitudinal study, Herman, et al., (2009) also reported moderate PA tracking in the final 15-years of tracking 374 Canadian participants (age 7-to-18-years) over a 22-year period, but not over the full 22-years. Weak associations were found between childhood and adulthood PA (r = 0.08-0.14) within a large Australian tracking study (Cleland, et al., 2012). Overall, total weekday PA in childhood did not predict adulthood PA; but in females, school PE predicted adult total weekly PA and daily step counts, and leisure and transport activity in childhood predicted leisure activity in males and females. Cleland, et al., (2012) recommended that despite modest associations between past and future PA promoting a range of PA to children of all ages in advisable. Limited findings may be from inconsistent measurements to record PA. Initially, at baseline, participants' self-reported frequency and duration of leisure and transport activity, and PE in a week, and number of sports played over the past year, and at follow-up, the participants were asked to complete a different questionnaire and wear a pedometer. Changing the method to assess PA may alter the PA results, as sensitivity between methods may be different.

One important study in Finnish participants tracked children from early childhood to middle adulthood over 27-years, PA was reported by mothers for children until age 9-years and was subsequently self-reported and suggests that PA at ages 3 and 6-years predicted PA in youth and young adulthood (Telama, et al., 2014). It was noted that PA patterns tracked moderate-to-highly from youth to adulthood and this was stronger in male participants than females. Whilst many studies have reported PA tracking throughout life course, even if poor, it is apparent that a physically active life may begin in early childhood and subsequently, must be considered an important age group when aiming to change life-long PA patterns. However, much of the evidence is drawn from international populations and may be unrepresentative of British children, especially considering Scandinavian countries report higher levels of PA. Further longitudinal studies using objective measures to capture PA to confirm tracking strength and examine PA determinants are required (Jones, et al., 2013).

2.2.8 Seasonal and Daily Changes in Physical Activity

Seasonal differences have been highlighted as potential influencers in PA levels (O'Brien, et al., 2018). Seasonal differences were observed in PA, when measured between 9 am and 5 pm, between autumn (159.9 ± 7.0) and summer (131.2 ± 6.8, $P < 0.05$; Finn, et al., 2002). Lower PA in summer is to be expected as temperature increases and therefore becomes too hot to be physically active, especially as temperature differences influence access to outdoor environments where PA is strongly correlated (Baranowski, et al., 1993; Schuna, et al., 2016; Mazzucca, et al., 2018; O'Brien, et al., 2018). The effect of poor weather has been identified as a barrier to PA (Tucker and Gilliland, 2007). Schuna, et al., (2016) found significant increases in sedentary time ($P = 0.033$), and declines in LPA ($P = 0.001$), MPA ($P = 0.001$) and MVPA ($P = 0.001$) from autumn to winter. Sedentary time and PA can, therefore, dramatically vary across seasons. Carson, et al., (2010) found Canadian preschoolers were most active in the summer and least active in winter, regarding active play ($P < 0.001$), weekday PA ($P < 0.001$) weekend PA ($P = 0.006$), and TPA ($P < 0.001$). However, Soini, et al., (2014) found that although there were significant differences in seasonal temperatures between autumn and winter ($P < 0.001$), significant differences were only found for weekday LPA ($P = 0.021$). When considering seasonal effects in preschoolers, geolocation and climate of the study may significantly impact results, because seasons may group the same months around the world (June, July and August as summer), there are significant differences between Norwegian winters and English winters, despite being in the same continent.

Another determent of PA is weekdays and weekend days. In children, weekday PA is superior to weekend day PA (Vale, et al., 2010; Bryant, et al., 2014; O'Dwyer, et al., 2014). In Portuguese children, Vale, et al., (2010) identified that males had higher weekday and weekend day TPA, and weekday and weekend day MVPA than females ($P < 0.05$). However, preschool children were significantly more engaged in weekday TPA and MVPA compared to weekend day PA ($P < 0.05$). Regarding MVPA compliance to recommendations, in both sexes, values of MVPA recommendations were significantly highest during the weekday in males ($P = 0.019$) and females ($P = 0.019$). Overall, 93.5% of children were reported to complete ≥60 minutes of MVPA during the week, and this significantly declined to 77.6% on the weekend ($P = 0.009$).

When measuring step counts in 6-to-11-year old British children, weekday steps were higher (males: 10514; females: 8830) than weekend day steps (males: 8819; females: 7314; Bryant, et al., 2014), although weekly significance was not assessed. Similarly, O'Dwyer, et al., (2014) observed PA difference between weekdays and weekend days. Overweight males participated in greater MVPA during the week (38.6 minutes) rather than weekends (34.0 minutes). Overweight females followed the same pattern and were more active during the week (38.0 minutes) than weekends (28.9 minutes). Non-overweight females showed very little difference between MVPA at weekends (42.4 minutes) and during the week (43.3 minutes). However, non-overweight males engaged in more MVPA during the week (45.2 minutes) compared to the weekend (38.0 minutes). Unfortunately, significance of weekday to weekend differences were not established in this study, but it does follow previous patterns of differences between daily PA in preschool aged children.

Conversely, Foweather, et al., (2015) identifies significantly higher VPA at the weekend when compared to weekdays ($P < 0.05$). However, Foweather, et al., (2015) reports no discernible differences in sedentary behaviour, TPA or MVPA in British preschoolers. Weekday sedentary time was 458.9 minutes compared to weekend day, 459.7 minutes; TPA was also similar between weekends (268.1 minutes) and weekdays (265.9 minutes). The study suggests that differences between VPA at weekday and weekends may be related to the increased flexibility at weekends which encourages more VPA.

However, the majority of these studies are cross-sectional in nature (Vale, et al., 2010; O'Dwyer, et al., 2011; Foweather, et al., 2015) or observed PA at one point in time (Bryant, et al., 2014), which means that causality between variables cannot be established. Additionally, all studies included children from only one metropolitan area, which makes generalisability difficult. The only significant changes identified were between MVPA, which was highest at the week (Vale, et al., 2010) and VPA, which was highest at the weekend rather than weekdays (Foweather, et al., 2015). Therefore, it may be of value to compare PA between weekday and weekends, by PA intensity. This may provide the subtle differences as where weekday and weekend day PA are different.

It is agreed that PA has relations with motor competence (MC) in preschool aged children, and that the relationship is bi-directional (Stodden, et al., 2008; Robinson, et al., 2015), but in British preschoolers it is unclear if PA contributes to MC or if MC contributes to PA.

2.3 Motor Competence

Fundamental motor skills (FMS) are a series of basic movements, comprised of a combination of patterns of two or more body sections (Gallahue and Donnelly, 2007). These skills are considered the building blocks for future more complex skills, which contribute to more specialised movement sequences (Gallahue, et al., 2011). 'Mastery' of such skills is identified as a prerequisite of participation in physical activities, sports and exercise (Cools, et al., 2009). Early childhood, between the ages of 2-to-6-years, is considered a 'window of opportunity' (LeGear, et al., 2012) for learning of FMS. Sophisticated patterns of FMS are not actions that are naturally learnt, but need to be rehearsed and perfected (Lubans, et al., 2010).

The Mountain Model of motor development (Clark and Metcalfe, 2002; Clark, 2005) and Seefeldt, (1980) both reference FMS in their models for motor development. Proficiency in FMS is also considered to be competent in motor skills, MC or physically literate, in locomotor MC (LC) and object-control MC (OC). Stodden and colleagues (2008; Figure 2.1) proposed a theoretical model that describes the interactives between development of MC, PA participation and

Figure 2.1: *Stodden et al.,'s., (2008) conceptual model of developmental mechanisms influencing the physical activity trajectories of children.*

Note: EC, early childhood; MC, middle childhood; LC, late childhood

weight management. The authors suggest that the early childhood years are where children begin to learn FMS, comprised of locomotor and object-control skills, and are an important stepping stone in motor development for lifelong PA. It is also suggested that children's PA is the driving force behind children's MC development, but this is a reciprocal relationship that feeds back into the spiral of engagement. Within the model (Stodden, et al., 2008) ,it is proposed that children in early childhood should demonstrate weakly associated MC and PA, but the relationship will strengthen over time, into middle and late childhood.

As previously discussed, increased adiposity is correlated with decreased PA in children, although this relationship is lesser seen in preschoolers (Bürgi, et al., 2011; Er, et al., 2018). Stodden, et al., (2008) suggest that increased adiposity will limit movement capabilities in children, as overweight children have greater difficultly performing motor skills, because of increased body mass (Goodway and Suminski, 2003). If these fundamental skills are not practiced, MC is likely to plateau, (Benelli and Benelli, 1995) which will decrease PA and increase sedentary behaviours. Being less active and more sedentary increases the risk of obesity, which ultimately feeds into a negative spiral of disengagement (Stodden, et al., 2008; Figure 2.1). A limitation of this model is the simplification of variables that may contribute to the spirals of engagement. For example, physical inability to participate in regular movement and inhibit PA in children (Landry and Driscoll, 2012), or genetics which make children more predisposed to certain obesogenic behaviours (like food preference, Lumeng, et al., 2008), or numerous other biological, psychological, sociocultural or environmental factors.

Adequate MC has been purported as contributory to physical, cognitive and social developments, as well as providing the basis for an active lifestyle (Lubans, et al., 2010). Several studies have documented MC amongst British preschool aged children (Foulkes, et al., 2015; Foweather, et al., 2015; Roscoe, et al., 2019), and international cohorts (Lopes, et al., 2016; Crane, et al., 2017; Brian, et al., 2018; Lopes, et al., 2018b). In British children, MC levels were found to be low in all skills, in males and females, except for run, slide and leap, with greater proficiency found in LC skills compared than OC skills (Foulkes, et al., 2015). Likewise, in Portuguese preschoolers, LC and OC scores are considered low Lopes, et al., 2016; Lopes, et al., 2018b). The percentages of children considered to have above average and average LC and OC scores was higher, when compared with American children, who had higher percentages of below average MC (Brian, et al., 2018). In both Belgian and American children, there were higher percentages of children scoring below average than expected, and lower percentages that scored above average. Likewise, Canadian children's percentage of the maximal possible motor skill score, at 57%, were considered as average proficiency (Crane, et al., 2017).

Comparisons among literature is difficult, as MC skills that are being assessed may have limited bearing cross-culturally, such as striking with a bat, which depending on sporting exposure, children may hold in a cricket or baseball stance. Additionally, methodological assessment tools differ between studies, with differences in which skills are assessed. There are several MC assessment tools that are used in this age range, the Test of Gross Motor Development-2

(TGMD-2, Ulrich, 2000) is perhaps the most widely used. What is clear, is current preschool aged children considered to have ‘average’ MC is lower than normative data, (Ulrich, 2000). But findings of lower MC are expected, as MC skills are still in the initial developmental stage and have not been perfected.

Several studies using the same MC assessment tool (TGMD-2; Ulrich, 2000), suggest that in early childhood, MC proficiency is regarded as ‘below average’ (Goodway, et al., 2010; Robinson, 2011; LeGear, et al., 2012; Bardid, et al., 2017; Crane, et al., 2017). Ulrich (2000) provides normative data regarding percentages of children between the ages of 3-to-10-years that demonstrate mastery of each LC and OC skill assessed in the TGMD-2, therefore to be regarded as ‘below average’ is concerning. Being proficient in MC will encourage PA engagement, so children who are ‘below average’ may be missing opportunities for PA engagement (Stodden, et al., 2008).

British studies have reported that preschoolers have ‘average’ LC and ‘average’ OC skills (Roscoe, et al., 2019) with international studies reporting similar findings. American children are considered to have ‘below average’ mastery in MC and high rates of developmental delays. Goodway, et al., (2010) suggests that American preschoolers showed developmental delays or were considered below the 30^{th} percentile, when comparing between the Midwest and Southwest. Developmental delays in OC are apparent in 85% of Midwestern and 84% of Southwestern children, and in LC are seen in 88% of Midwestern and 91% of Southwestern children. Similarly, Robinson, (2011) reports that American children in a Midwestern city were considered ‘below average’ in both LC and OC. Canadian children’s LC and OC in males and females are also considered to be ‘below average’ (LeGear, et al., 2012; Crane, et al., 2017). In Belgian children, Males LC and OC and females LC are considered ‘average’ and just females OC is considered ‘below average’ (Bardid, et al., 2017). This pattern was the same in Portuguese early years children (5-to-7-years; Lopes, et al., 2018b). In Australian studies, LC and OC in males and females are widely reported to be ‘average’ (Cliff, et al., 2009; Hardy, et al., 2010; Barnett, et al., 2016b).

Differences between countries may be due to higher PA, which was inferred by Stodden, et al.,'s (2008) model and reported previously. Additionally, preschool physical education programmes may also contribute to MC differences. For example, in Belgium, almost all Belgian children attend preschool and physical education starts at age three (Haerens et al., 2014), which could potentially encourage better MC development at younger ages. These cultures and countries are different to the UK, as a result, assumptions should not be made based on non-UK samples.

2.3.1 Motor Competence and Weight Status

The conceptual model suggests that MC is both a precursor and consequence of weight status (Stodden, et al., 2008). During a systematic review, Lubans, et al., (2010) highlights that nine studies assessed relationships between MC and weight status. Lubans, et al., (2010) concludes that, from cross-sectional studies only, that inverse associations exist between MC and weight status and suggest that enhanced MC will have positive impacts on weight reductions or reduce the risk of unhealthy weight gain. Likewise, Barnett, et al., (2016a) found comparable assertions. Higher BMI was negatively correlated with MC and interestingly there was no evidence for BMI being associated with (positively, or negatively) with OC or LC. This was also the case in other measures of adiposity, such as higher waist circumference and body fat percentages having negative correlations with MC. Han, et al., (2018) also reviewed literature to conclude that childhood obesity is inversely associated with MC which becomes a 'vicious cycle'. Improving MC may contribute to preventing that cycle in overweight and obese children. However, few studies have explored this specifically in children in early childhood or under 6-years (Han, et al., 2018).

In British preschool aged children, Roscoe, et al., (2019) found no significant weight status differences in children with low-to-high mastery. This possibly was because, in early childhood, MC has not developed enough to influence PA and adiposity. Within a prospective study, Bryant, et al., (2014) tracked 281 British children's (8.9 ± 1.4 years) MC and weight status. In addition to seeing increases in overweight children, MC was a significant predictor of current weight status, measured as BMI *(P* = 0.01) and body fat percentage *(P* = 0.005). Similarly, Duncan, et al., (2013) used the functional movement screening, to identify that MC was significantly negatively correlated with BMI *(P* = 0.0001) in 90, 7-to-10-year old British school children. Children that were overweight had significantly lower levels of motor competency, compared to healthy weight children *(P* = 0.0001). Weight status differences may become apparent as children age as the relationship between MC and PA strengthens, which has impacts on adiposity (Stodden, et al., 2008).

2.3.2 Motor Competence and Health

Other health benefits are associated with MC, like muscular fitness and flexibility, cardiorespiratory fitness, strength, endurance, flexibility and BMI (Lubans, et al., 2010). However, Lubans, et al., (2010) makes it clear that due to the limited number of studies, any relationships between MC and fitness components are classified as uncertain. In a more recent review Cattuzzo, et al., (2016) concluded that 81% of studies in youth demonstrated a strong association with body weight status; 100% demonstrated strong associations with cardiorespiratory fitness; 63.6% demonstrated strong associations with musculoskeletal fitness; and 75% demonstrated uncertain associations with flexibility. Cattuzzo and colleagues (2016) infer that increased MC leads to increased PA, which in turn supports health related physical fitness.

Strong and significant correlations were demonstrated between MC and physical fitness Norwegian preschoolers (Sigmundsson and Haga, 2016). Children's MC was significantly associated with physical fitness *(P* = 0.0.01), and physical fitness was associated with manual dexterity *(P* = 0.01) and balance *(P* = 0.01). In males, physical fitness was associated with overall MC *(P* = 0.05) and balance *(P* = 0.01), and in females, physical fitness was associated with overall MC *(P* = 0.01), manual dexterity *(P* = 0.01) and balance *(P* = 0.01). Sex-differences in physical fitness suggest the potential activity choices by males and females, possibly as females may choose to engage in activities that would improve physical fitness and manual dexterity performance (Sigmundsson and Haga, 2016). It is important to note that ball skills were not associated with physical fitness in these children, which may be due MC development in manipulative skills (such as OC skills) happening later in childhood, or that some of these skills do not involve movements to improve physical fitness, like catching and throwing.

2.3.3 Motor Competence and Physical Activity

It is hypothesised (Stodden, et al., 2008) that low MC contributes to a negative spiral of disengagement in PA, as those who are less competent in MC will fail to enjoy PA, which will reduce exposure to MC practice, and so forth. The model predicts that in early childhood, engaging in PA will improve MC proficiency as this is where MC is practiced. Therefore, the relationship between PA and MC is bidirectional. Children with better MC skill ability often report enjoying more physically active play than those who are not proficient in MC (Solmon, et al., 2003), and will continue to engage in PA as a result.

Associations between PA and MC in preschoolers are inconclusive. In 4-year old Finnish children, MC was not associated with MVPA, within inside *(P* = 0.088) or outside *(P* = 0.070) environments (Iivonen, et al., 2016). This could be due to the low PA levels and high sedentary behaviours in this cohort, as 70% of observed activity was classified as sedentary, which would not allow for adequate development of MC. Additionally, PA assessed using observational methods on a five-point scale, that reflected the highest interval reach by the child during a 15-second interval. Therefore, subtle changes in PA may have been missed, and may contribute to no significance found. Matarma, et al., (2017) identified similar patterns in Finnish 5-to-6-year old children, of no significant associations between objectively measures MVPA and sedentary time and MC. However, accelerometery was used to assess PA. Bouvin, et al., (2013) found no associations between MC and accelerometery measured PA in 2-to-4-year old children. Lack of associations may be attributed to using the ‘Zurich Neuromotor Assessment’ to assess motor skills, which is standardised and reliable in 5-to-8-year old children, so may not be age and stage appropriate. All three of the aforementioned studies purport that MVPA has limited associations with MC but failed to incorporate TPA in addition to MVPA. Likewise, no MC and PA associations were seen in 101 Portuguese preschoolers (4.7 ± 0.84 years; Lopes, et al., 2016).

Conversely, Slykerman, et al., (2016) reports some associations in MC and PA in Australian 5-to-8-year olds. Males were significantly more active and had higher OC *(P* < 0.001) than females. In females, LC was a significant predictor of MVPA *(P* = 0.016), but not in males. In slightly younger Australians, Cliff, et al., (2009) found OC was associated with MPA in males *(P* = 0.008) and MVPA *(P* = 0.015) and LC was associated with MPA *(P* = 0.015) and MVPA in females *(P* = 0.022), when PA was expressed as a percentage of time. Both of the prior studies report LC and PA associations in females, but the reasons are unclear. It may be a result of females engaging in LC based PA, like ballet, dance and gymnastics, which develops LC but not OC (Slykerman, et al., 2016). Barnett, et al., (2016b) found that MVPA at 3.5 years contributed to subsequent LC *(P* = 0.033). Interestingly, preschool children who spent 15 minutes per day in VPA would demonstrate 1-unit higher for LC, described as the equivalent to performing a component of a skill correctly, which may over time, help increase mastery, which will increase PA opportunities. Young children need specific opportunities for skills to be taught and practiced (Barnett, et al., 2016b).

In American children, MC was significantly associated with PA (Beets and Foley, 2008; Williams, et al., 2008; Robinson, 2011). In 5-to-6-year old children, MC was significantly associated with parental-reported PA *(P* = 0.0001; Beets and Foley, 2008). Beets and Foley (2008) assessed MC with balancing, hopping, skipping and walking backwards; without involving any manipulative skills, such OC skills, and only provides a limited view-point of MC. Additionally, PA was assessed by parents, with comparison responses as "less active", "about the same" or "more active" than other children the same age. Whilst these methods provide ease for assessment of large numbers of participants, it can provide bias as parents are susceptible to overestimating PA (Hesketh, et al., 2013; Lau, et al., 2013). Williams, et al., (2008) categorised 198 3-to-4-year old children into groups based on MC performance. The children in the high MC tertile were significantly more engaged in MVPA *(P* =0.05) and VPA *(P* = 0.01). Children with the highest tertile for LC engaged in significantly more MVPA *(P* = 0.05) and VPA

(P = 0.01) but OC did not demonstrate significance associations with PA in any intensity (Williams, et al., 2008).

During a prospective study (Famelia, et al., 2016), Indonesian children aged between 3-to-6-years, regressions identified that ball skills did not predict the percentage of time in either sedentary behaviour *(P* = 0.25) or MVPA *(P* = 0.32), but locomotor skills predicted sedentary behaviour *(P* = 0.04) and MVPA *(P* = 0.04). However, children in this cohort were particularly inactive, as ~80% of time was sedentary and only 7% was spent in MVPA in school, and during ‘playground time’, children were still sedentary (70%) and engaged with less than predicted MVPA (15%).

There is no strong evidence of significant associations in MC and PA in British preschoolers. Roscoe, et al., (2019) identified no significant correlations between MC, as total, LC and OC, and weekday and weekend MVPA in 185 children aged between 3-to-4-years. However, it is important to note that within this cohort, no children achieved ≥180-minutes of TPA, as recommended by UK PA guidelines and are insufficiently active. This was possibly because MC mastery was not sufficiently developed to impact MC and PA associations. Foweather, et al., (2015) explored MC associations with weekday and weekend PA in 99 children aged 3-to-5-years. Males were more active than females and had enhanced OC. Total MC score was associated with weekend MVPA *(P* = 0.034); OC was associated with weekday LPA *(P* = 0.008), weekend LPA *(P* = 0.033), weekend MVPA *(P* = 0.028) and weekend TPA *(P* = 0.008); LC was associated with weekday MVPA *(P* = 0.016) and weekend LPA *(P* = 0.035). These findings are probably indicative of PA patterns between weekdays within childcare settings or weekends when lacking structured routine.

Much of the literature in international populations investigated the associations between MVPA and MC, and thus, did not explore how intensity of PA may change association strength with MC. Foweather, et al., (2015) demonstrated how each intensity of PA may have differing associations with MC, separated as OC and LC, going so far as to separate PA into weekday and weekend categories. However, inclusion criteria for PA was three days, including one weekend day, for ≥540 minutes per day, with uniaxial accelerometers. A limiting factor of uniaxial accelerometery is the low sensitivity to accurately quantify PA levels in younger populations (Hislop, et al., 2013). Additionally, as discussed later (Methodology Review, Page 54), to establish habitual PA patterns, inclusion of one weekend day over ≥3-days, with ≥600 minutes per day is considered to be sufficient (Hinkley, et al., 2012; Cain, et al., 2013; Hislop, et al., 2014).

2.3.4 Actual and Perceived Motor Competence

Perceived competence refers to an individual's perception of their actual motor proficiency (Lubans, et al., 2010). Actual MC interacts with perceived MC and is a mechanism that influences engagement and persistence with PA (Stodden, et al., 2008; Robinson, 2011). It has been proposed that actual MC is developed before accurate perceived MC occurs, and perceived MC has stronger influence on direct motivation than actual MC (Harter, 1978).

Within the conceptual model, Stodden and colleagues (2008) believe there has been limited advancement in understanding casual predictors of obesity and physical inactivity, partially as a result of understanding the mediating role perceived MC has on associations of PA over time, from early to late childhood. In early childhood, perceived MC is considered inaccurate because perceived MC in inflated compared to actual MC (Harter, 1999). Young children, like those in early childhood, are yet to develop cognitive skills to accurately differentiate between actual skill performance compared to ability and effort and will perceive higher effort exertion similarly to MC proficiency (Harter, 1999). Stodden, et al., (2008) predicts that in early childhood, perceived MC and actual MC or PA may not be associated. But suggest that inflated perceived MC may contribute to MC skill acquisition and improvements. Children are more inclined to participate in activities they perceived themselves good at as they enjoy them more (Bult, et al., 2014). Engagement in MC activities increases as enjoyment remains high, which improves MC proficiency, which then encourages PA participation. Furthermore, children's perceptions are influenced by feedback, either supportive or critical, from parents and teachers, and will be more inclined to participate in activities they are told and believe to be good at (Muenks, et al., 2018).

Feitoza, et al., (2018) conducted a cross-cultural study across four countries, including 231 Brazilian, 129 Australian, 140 Portuguese and 114 American children aged 5-to-8-years. Perceived MC was found to be significantly different between countries, in favour of American females and Brazilian males. Indonesian preschoolers felt they were "pretty good" when perceived MC was measured via two assessment tools, Perceived Physical Competence subscale (PPC) and Perceived Movement Skill Competence scale (PMSC; Famelia, et al., 2018). There were no significant sex-differences between PPC (P = 0.58) or PSMC (P = 0.33). Ball skills predicted 7.7% of the variance in PPC, but no predictors were identified for PMSC.

Barnett, et al., (2008) found OC skill in childhood was positively associated with higher perceived MC in Australian adolescents. Similarly, in Midwestern American preschoolers, males had significantly higher perceived MC (P = 0.001) than females (Robinson, 2011). Perceived MC was associated with overall MC (P = 0.001), LC (P = 0.001) and OC (P = 0.001) collectively, and with males and females separately (P = 0.005). In a cross-cultural comparison study, Belgium and American preschoolers' perceived MC was associated with OC (P < 0.01), but not LC (Brian, et al., 2018). In Portuguese preschoolers (4.9 ± 0.93 years), balance and perceived MC were associated (P = 0.05), but no other associations were identified (Lopes, et al., 2016) suggesting that differences in OC are more strongly associated with perceived MC.

During a separate cross-sectional study, PA, actual and perceived MC associations were investigated (Slykerman, et al., 2016). Males significantly predicted themselves as more proficient in OC than females (P =0.002). In females, only LC was a significant predictor of MVPA, but perceived MC had no associations in either males or females with PA or MC. In a differing study, perceived MC was not significantly related to MVPA (P = 0.323) in young children (4-to-5-years) but was significantly related to MVPA (P = 0.026) in older children (5-to-8-years), suggesting that perceived MC has direct implications on PA as children age (Barnett, et al., 2017). Over two years, 250 Canadian children (5.8 ± 0.3 years) had their actual and perceived MC assessed (Crane, et al., 2017). In preschool females, 10% and 9% of variance in perceived MC was explained by LC and OC skills respectively. In preschool males, perceived MC was explained by 7% and 11% variance from actual LC and OC skill. When children were reassessed (7.7 ± 0.4 years), perceived MC had risen *(P* = 0.040), and sex-differences were observed *(P* = 0.044), revealing females had higher perceived MC. At follow-up, LC and OC predicted 11% and 19% of variance in MC perceptions in males only. Relations between actual and perceived MC strengthened as males aged, but not in females, thus, some other variable may be influencing perceived MC.

In British children, a total of 258 children (4-to-7-years; 5.6 ± 0.96 years) were classified as 'low' 'medium' or 'high' perceived MC based on a tertile analysis (Duncan, et al., 2018). Actual MC was assessed by process measures (TGMD-2) and product measures. Males had significantly higher scores in product *(P* = 0.044) and process *(P* = 0.001) measures for actual MC, and perceived MC *(P* = 0.040). Children with medium and high self-perceptions had higher process *(P* = 0.001) and product *(P* = 0.001) MC. There was no difference between those classified as medium and high perceived MC *(P* = 0.99).

To summarise, there are sex-differences observed in perceived MC, usually reported as males with higher perception scores (Robinson, 2011; Feitoza, et al., 2016; Slykerman, et al., 2016; Crane, et al., 2017). In this age range, actual and perceived MC are not reported to be associated (Lopes, et al., 2011; Famelia, et al., 2016), but if associations are reported, they are with OC skills, not total and LC (Barnett, et al., 2008; Brian, et al., 2018).

The conceptual model of Stodden, et al., (2008) that proposes actual MC relates to PA, and is indirectly mediated through its relationship by perceived MC. Some literature has demonstrated that there is a mediating effect present from perceived MC in older children. Perceived MC mediates the relationship between LC skill and PA in Iranian females aged 8-to-9-years old. (Khodaverdi, et al., 2015) and mediates between actual OC skills and PA in Australian adolescents

(Barnett, et al., 2008; 2009). In a parallel study, perceptions of MC mediated the associations between Australian adolescent OC and MVPA bi-directionally, but perceived MC only mediated the associations between MVPA and LC when LC was the outcome variable (Barnett, et al., 2011). In one study in early childhood, Crane, et al., (2017) demonstrated that perceived MC did not mediate the associations between PA, as both TPA and MVPA, and MC, as LC and OC in Canadian children (age 5-years 7-months).

The mediating role of perceived MC in early childhood has not been widely explored in any other countries, but its role should not be diminished. The conceptual model (Stodden, et al., 2008) suggests that as children age the role perceived MC plays becomes more dominant. There is evidence that high self-confidence has been strongly associated with perceived MC (Barnett, et al., 2008). In addition, children are more inclined to withdraw from participating with PA, for fear of demonstrating low MC (Harter and Pike, 1984). Declining confidence may lead to decline in PA participation and engagement in MC skill development opportunities (Stodden, et al., 2008). Whilst perceived MC may not have direct impacts in early childhood, its future role, may alter MC proficiency and PA engagement.

2.3.5 Sex-Differences in Motor Competence

In young children, before biological maturation, it is expected that there will be limited sex-differences in MC (Malina, et al., 2014). Several studies report no significant sex-differences in MC, in any component in preschoolers (Nervik, et al., 2011; Lopes, et al., 2016). However, there are widely reported sex-differences in preschool children. In American children, male preschoolers are significantly more proficient in MC (P = 0. 0.001), LC (P = 0.002) and OC (P = 0.001) than females (Robinson, 2011). In males, significant but small correlations are reported between perceived MC, and MC (P = 0.05), LC (P = 0.05) and OC (P = 0.05). In females, small but significant correlations are reported between perceived MC and OC (P = 0.05), but moderate and significant relationships were identified with total MC (P = 0.05) and LC (P = 0.05).

Yet, some studies have reported that females are more proficient in one aspect of MC and males are in another. Hardy, et al., (2010) identified that females were more proficient in LC skills *(P* = 0.005), but males obtained higher OC *(P* = 0.001), although no sex-differences were observed in total MC *(P* = 0.87) in Australian preschoolers. Several studies agree that OC are significantly more proficient in males compared to females (LeGear, et al., 2012; Foulkes, et al., 2015; Foweather, et al., 2015; Crane, et al., 2017; Roscoe, et al., 2019). Additionally, females are more proficient in LC skills (Cliff, et al., 2009; Crane, et al., 2017; Roscoe, et al., 2019).

It is not clear why sex-specific differences in MC are apparent in early childhood. Locomotor MC may be a more natural part of females play, seen in dance or gymnastics, and males engage in a variety of LC and OC skills. It would be expected that sex-differences are not apparent as biological maturation occurs in later childhood. Consequently, any observed sex-variations are likely from other external factors on the children, such as cultural or societal impacts. Rivers and Barnett (2008) suggest such differences are an outcome from adult-children interactions, where society's perceptions are that males and females' brains are "wired" differently and as a result, children are treated differently based on sex, rather than ability. Furthermore, Rivers and Barnett (2013) also suggest that expectations from adults are different between male and female children's capabilities of tasks, which in turn affects how adults interact with these children, and therefore whether children continue to participate in such tasks. Specifically, Rivers and Barnett (2013) suggest that parents engage in more physical skills and PA with males, and less with females; and encourage more verbal discussions with females and less with males. It is unsurprising that there are sex-differences in LC and OC. If males are being encouraged to engage with MC and PA by adults, and females are being encouraged to 'chat' instead, this will likely cause sex-differences, as females will not be exposed to the same opportunities to engage in MC development. Furthermore, Barnett and Rivers (2013) discuss the misguided preconceptions that females are more nurturing and are applauded when engaging in nurturing play, and males are more active and encouraged to engage in more 'rough and tumble' play.

2.3.6 Determinants of Motor Competence

MC may be dependent on biological determinants, like age and physical capabilities, as well as parental influence and childcare attendance. Age has consistently been shown to be a determinant of MC (Lubans, et al., 2010; Iivonen, et al., 2011; Lopes, et al., 2011; Robinson, et al., 2015; Barnett, et al., 2016), as when children age, MC proficiency naturally develops, because children develop the abilities to stand, walk and run (Strong, et al., 2005) and this progresses to development of other MC skills, like jumping, hopping and throwing. However, if a child has an impairment, like a physical or mental disability, MC will be lower than in children who do not (Emck, et al., 2009; Haga, 2009), due to hindrances in their capabilities to process and perform such skills (Haga, 2009).

Additionally, parents have been shown to have strong influences on MC in children, as parents that encouraged MC activities, had children that were more MC proficient, than parents who did not (LeGear, et al., 2012; Barnett, et al., 2016). Furthermore, parents that were confident in their own MC abilities were more likely to have more MC proficient children (Barnett, et al., 2013).

2.3.7 Motor Competence, Ethnicity and Socioeconomic Status

Few studies have investigated the role ethnicity has on MC in preschool aged children. One study in Australian of 9-to-11-year old children (Barnett, et al., 2019), European-Australian children's BMI was significantly higher than their Asian-Australian counterparts (P = 0.049). Significant differences were observed in OC skills (P = 0.029) but no significant differences were observed in LC (P = 0.638). Ethnicity differences may have occurred due to the use of the TGMD-2 to assess MC. The TGMD-2 is a validated measure of MC in children, but it is American centred, as sports popular in America, like basketball and baseball which have less exposure in other countries, like Australia. Therefore, children may underperform in MC assessment due to skills in the assessment being relatively new. It would be of interest for a study to explore weight status, PA and MC in early years children when comparing ethnicity.

Socioeconomic status is thought to have some influence on MC in young children, however, few studies have examined socioeconomic status differences in preschool children. Morrison, et al., (2018) found that average area household income was significantly correlated with motor performance in Dutch children, aged between 8-to-11-years old. Males' motor performance was significantly correlated with household income *(P* = 0.01), as did females *(P* = 0.05). Socioeconomic status may influence MC, as opportunities to participate in PA is more widely available in higher income areas (Morley, et al., 2015) and parents of higher socioeconomic status are more inclined to encourage their child to participate in MC developing activities, such as swimming and dancing which have financial outgoings (Laukkanen, 2016).

2.4 Justification of Research Study

The promotion of PA has been identified as a public health priority, particularly, encouraging children to be sufficiently activity for health benefits (Department of Health, 2018). The preschool age group has been acknowledged as an important age group for PA promotion. It is postulated that as children age, they will become less physically active. Moreover, MC has been identified as an important part of a child's development, and it is understood that MC proficiency will aid an active lifestyle (Cools, et al., 2009). By understanding the associations between MC and PA in British preschool children with regards to BMI, will enable better health promotion. By comprehensive understanding of how these components are related, will provide the basis for health protection and improvement.

Several studies have explored associations between PA and MC in preschool populations internationally (Beets and Foley, 2008; Williams, et al., 2008; Cliff, et al., 2009; Bouvin, et al., 2013; Barnett, et al., 2016b; Iivonen, et al., 2016; Lopes, et al., 2016; Matarma, et al., 2017) and in older populations (De Meester, et al., 2016; Khodaverdi, et al., 2016; Duncan, et al., 2018), but there is a sparsity of information regarding the associations in British preschool children. This important and under researched age group is therefore, in a need of examination, particularly the directional nature of the associations between BMI, PA, actual and perceived MC to be explored in British preschoolers.

The overarching aim of this thesis was to examine the relations between PA, MC, weight status, and perceived MC in a British early childhood population. Thus, this thesis followed a three staged approach to unpick the tenants of the conceptual model (Stodden, et al., 2008).

Firstly, a cross-sectional study shall explore associations between PA, MC and weight status. The conceptualised model (Stodden, et al., 2008) suggests that each of the three variables are associated, but this is yet to be done in British preschoolers with PA cut-off points designed for British preschoolers. It is speculated that PA and MC will demonstrate associations as previous literature has identified such associations in international or older populations. The associations will not include OC as in early childhood, OC skills may not be sufficiently developed for differences in competency to be apparent.

Secondly, a cross-sectional study to assess the mediating capabilities of perceived MC on associations between PA and actual MC, which has yet to be conducted in a British population. It is expected that there will be no mediation present as in such a young age, children do not possess the cognitive ability to accurately assess their own MC performance.

Thirdly, a longitudinal study tracking PA, MC and BMI from baseline to follow-up a year later to empirically assess assumptions in the conceptualised model (Stodden, et al., 2008) that in early childhood PA contributes to MC in a British population; and to identify is MC or PA contribute to BMI in such a young population. It is hypothesised that PA will contribute to MC as suggested, because in order for children to practice MC skills, they must be incorporated into PA tasks.

3 Methodology Review

Several assessment methods exist to measure weight status, physical activity (PA), actual motor competence (MC) and perceived MC. This chapter will explore such methods, describing strengths and limitations of each to highlight which assessment methods will be employed in this thesis.

3.1 Weight status and Body Composition

Assessing body composition, to establish weight status, is complex. The human body is made up of a range of components, such as water, fat mass, protein and minerals (Pietrobelli, et al., 1998). Identifying body composition in children is particularly difficult as children are often unwilling to participate in assessment methods (Deurenberg, et al., 1990) or are at various growth stages which can temporarily alter body composition and are individual to each child (Rolland-Cachera, et al., 2007). There are various methods for body composition assessment, but many of these are not necessarily practical in young children (Rolland-Cachera, et al., 2007).

3.1.1 Bioelectrical Impedance Analysis

Bioelectrical impedance analysis (BIA) provides comprehensive body composition from fat mass and fat free mass. This method provides a more detailed overview of body composition than BMI and waist circumference, but it does have its detriments (Tyrell, et al., 2001). Some BIA machines are relative transportable, the results can be misrepresentative depending on hydration status. As electrical impulses are sent round the body to make assessments of body composition, hydration status can affect conductivity of tissues in the body (Tyrell, et al., 2001) so, prior knowledge of current hydration levels is important when using BIA.

In young children, aged 4-to-11-years, BIA correlates with fat-free mass, fat mass and body fat percentage (Tyrell, et al., 2001). BIA is a validated method for use in children that provides more detail than BMI and waist circumference. However, accessibility to such machines can be limited, and reliability between machines can often be low (Houtkooper, et al., 1992). Furthermore, BIA has also been shown to underestimate the fat mass in both sexes in children and as such not recommended for use in young children (de Castro, et al., 2018).

3.1.2 Dual-energy X-ray absorptiometry

Dual-energy X-ray absorptiometry (DEXA) is a non-invasive measurement of bone mineral density that has been shown to provide high accuracy when assessing body composition (Shepard, et al., 2017), but has been shown to underestimate whole body fat mass by as much as 5 kg (Kullberg, et al., 2009). Furthermore, this machine is impractical to be taken in field as it must remain in one location as well as being expensive (Shepard, et al., 2017). Additionally, it provides small radiation outputs and consequently, it would be immoral, unreasonable and unfeasible to be used when assessing preschool aged children (Shepard, et al., 2017).

3.1.3 Skinfolds

Skinfold assessment assesses subcutaneous fat and used to estimate body fat percentages (Wendel, et al., 2017). Results from skinfold assessments have been shown to have excellent agreement with other body composition techniques, such as DEXA (Wendel, et al., 2017). However, measurements of skinfold thickness require training and can be perceived as painful by children (Snik and de Roos, 2019). Furthermore, children's compliance to skinfold assessment may be limited, which reduces applicability to assess weight status or body composition in preschoolers. The practicalities of skinfold measures, which is invasive and painful to children, meant this method would be difficult to justify is such young children.

3.1.4 Body Mass Index

The most widely used method of assessment is the body mass index (BMI) which is a quick, cheap and portable measure of weight status in children that correlates with total body fat (Bell, et al., 2018; Nyström, et al., 2018). BMI is limited by small inabilities to differentiate between 'healthy' weight and 'unhealthy' weight, as lean mass and fat mass are combined to give a weight result, which contributes to BMI. When using BMI to categorise weight status it is recommended that using age and sex percentiles limits errors in classifications. High BMI, for age, in children is recommended as an acceptable diagnostic tool for accurate body fat content (Adab and Pallan, 2018).

Weight status can be devised from BMI *z*-scores, also called BMI standard deviation scores, which are measures of weight, adjusted for age and sex (Must and Andersen, 2006), however BMI is widely used across much research, by public health professionals and understood by the general public. It provides a numerical output which is dependent on height and weight of a child, which allows for comparison between individuals. As a popular assessment tool to classify weight status, the simple and practical BMI is considered to be an appropriate approach to classify weight status in early childhood.

3.1.5 Waist Circumference

Waist circumference is another relatively simple method to assess weight status that correlates with visceral fat and is a better predictor of overweight and obesity than BMI (Snik and de Roos, 2019). Currently, there are no standardised waist circumference for age reference points, which makes establishing weight status impossible.

Specifically, in children, assessment of waist circumference can be difficult, as children are not always responsive to removing clothes from the area to measure the waist. Whilst this assessment has limitations on its own, when used with another weight status measure, can provide more detailed information regarding visceral adipose (Reilly, 2006). However, as a method to identify weight status, waist circumference has no reference points and therefore, was considered impractical.

3.2 Physical Activity

Measurement of children’s physical activity (PA) can be conducted in various ways, with objective, subjective and observational methods. Studies agree that the more PA is tracked, the more accurate the results will be (Penpraze, et al., 2006; Choi, et al., 2011). In the preschool age range, the quantity of days was more important in the reliability of habitual PA than the volume of hours, as inclusion of weekend days provided little difference (Penpraze, et al., 2006). Hinkley, et al., (2012) concludes that at least one weekend day should be included in a study to improve reliability when assessing PA in preschool children.

3.2.1 Subjective Measures of Physical Activity

Subjective measures of PA include self-reporting and questionnaires. Questionnaires are advantageous as they are inexpensive and non-invasive measures that can be used in large scale investigations (Oliver, et al., 2007). Questionnaires can provide nuanced information but distinguishing between intensities is difficult to achieve when reports are subjective (Oliver, et al., 2007). Nevertheless, questionnaires are a validated and reliable method to assess PA (Helmerhorst, et al., 2012).

In preschool aged children, self-reporting is not recommended as children at this age lack cognitive or verbal abilities to accurately recall details of PA patterns (Sallis, et al., 2000). Parental-reported questionnaires whilst recommended also have the potential for inaccuracies as it has been reported in the early years that parents overestimate PA (Hesketh, et al., 2013; Lau, et al., 2013). Lau, et al., (2013) suggests that parents of children aged 5-to-7-years, consistently overestimate their children's accelerometery measured PA (P = 0.01). Hesketh, et al., (2013) reports similar findings, as 89.7% of parents of inactive children believed their children were sufficiently active. Additionally, the majority of children's PA is categorised as active play, which can cause confusion when reporting historical PA (Riddoch, 2004). Inaccuracies from reports are problematic in this age group, therefore rendering subjective measures of PA limiting and impractical.

3.2.2 Object Measures

3.2.2.1 Pedometers

Pedometers are a type of activity monitor that are simple and provide objective measures of PA, via step count (Tudor-Locke, et al., 2006) and have been validated in preschool children (Oliver, et al., 2007; de Vries, et al., 2009).

Pedometers provide ambulatory activity levels, measured by movement of the body along the vertical plane (Pate, et al., 2010). Step counts provide a rudimentary number to distinguish between PA levels, (de Vries, et al., 2009).

Similarly, to questionnaires, pedometers do not provide information on frequency, intensity, and duration of activity (de Vries, et al., 2009). Consequently, data provided misses out on PA patterns throughout the day that would not be apparent with only step counts. Evidence suggests that in primary school aged children, to accumulate ≥60 minutes of moderate-to-vigorous PA, total step counts need to be ≥11000 (Tudor-Locke, et al., 2004). Furthermore, output data is non-comparable between studies, as gait and stride length between age-groups are not standardised (Corder, et al., 2008). Use of pedometers provides some insight into habitual PA but is limited by inability to distinguish between PA intensity, corresponding with PA recommendations.

3.2.2.2 Accelerometers

Accelerometers are a different type of activity monitor that objectively assessed PA via acceleration. Accelerometers detect acceleration or change in velocities over time (Corder, et al., 2008). Use of accelerometery has increased in recent years, due to technological advances (de Vries, et al., 2009). In preschool children, accelerometers have been agreed as a validated and reliable measure of PA and sedentary behaviour (Choi, et al., 2011; Esliger, et al., 2011; Janssen et al., 2013; Roscoe, et al., 2017; Bisson, et al., 2019). Advantages of using accelerometery are the raw outputs of data which can be interpreted into frequency, intensity and duration of PA; in addition to the long-lasting battery-life and memory, which is not seen with pedometers. There is initial low research burden with accelerometers, which contributes to this PA assessment measure being one of the most frequently used methods (Oliver, et al., 2007).

Wear time to establish habitual PA patterns with accelerometers is widely debated, Penpraze, et al., (2006) suggests that number of days was more important than weekday to weekend day ratio and the number of hours per day PA was assessed for. Conversely, Hinkley, et al., (2012) suggests that at least one weekend day should be included in the study. In British primary school children, it has been reported that ≥2-days of a minimum of ≥600-minutes is sufficient to provide reliable estimates of PA (Cain, et al., 2013). Furthermore, Hislop, et al., (2014) suggests in preschool aged children (3.7 ± 0.7 years) that 3-days of accelerometery monitoring regardless of recording a weekend day is sufficient if all 3-days have ≥420-minutes, is sufficient to accurately assess PA and sedentary behaviour. Therefore, inclusion of one weekend day, over 3-days of recording PA with ≥600 minutes per day was interpreted to be sufficient (Hinkley, et al., 2012; Cain, et al., 2013; Hislop, et al., 2014).

There are several types of accelerometers, uniaxial, omnidirectional and triaxial. Uniaxial accelerometers measure on the vertical plane, omnidirectional measure acceleration in any direction, and triaxial measures on the vertical, anteroposterior and mediolateral planes (Van Hees, et al., 2011). Uniaxial accelerometers are widely used with preschool children (Vale, et al., 2010; O'Dwyer, et al., 2011; Foweather, et al., 2015), but it is unclear whether, in this age group, uniaxial is acceptable (Sirard and Pate, 2001). Uniaxial accelerometers may not be sensitive enough to quantify accurate PA levels, especially in young populations (Hislop, et al., 2013).

Accelerometers are limited by capability to assess static PA and non-weight bearing activities that require little body movements (Strath, et al., 2012). Raw data output is large, and interpretation can be time consuming to interpret into PA counts. But, accelerometery is considered the best option to assess PA, as the raw output of data can be explored via intensity cut-point thresholds or raw acceleration data (de Vries, et al., 2009). Wrist placement of accelerometers has been validated in preschoolers (Roscoe, et al., 2017) and has been shown to have higher compliance to wearing accelerometers in young children (Migueles, et al., 2017).

There are two widely used accelerometers in PA literature, ActiGraph and GENEActiv accelerometers (Noonan, et al., 2017). Both ActiGraph and GENEActiv accelerometers have shown to be acceptable to be used when assessing children's PA (Noonan, et al., 2017). But higher wear time has reported in GENEActiv accelerometers, compared to ActiGraph accelerometers (Noonan, et al., 2017). GENEActiv accelerometers have been validated in preschool aged children (Esliger, et al., 2013; Phillips, et al., 2013) and have previously been used in this young population in previous literature (Roscoe, et al., 2017). Furthermore, the cut points to quantify PA intensity using GENEActiv accelerometers have been developed in British preschoolers (Roscoe, et al., 2017), thus GENEActiv accelerometers are an attractive measure of PA in this population.

3.3 Motor Competence

There are several motor competence (MC) assessment tools that can be used depending on the criteria for assessment (Cools, et al., 2009). Assessment of MC can be evaluated through both process and product measures. Process measures assess movement patterns and provide qualitative data regarding the quality of movement patterns (Hardy, et al., 2010). Product-based measures are quantitative and predominantly focus on outcomes of movements, such as time, speed or distance (Logan, et al., 2017). Using process-based measures, in the preschool ages, provides the opportunity to identify the level of development each individual is at, which is useful when children within this age group are still learning and developing MC skills (Hardy, et al., 2010). Assessment methods are available to be completed in real time, or subsequently via video recordings. Moreover, assessment of preschoolers' MC can be challenging in large-scale studies that involve large numbers of preschool aged children (Williams, et al., 2008). To appropriately assess the effects of MC, reliable and accurate assessment measures are needed, which will be discussed in the following sections.

3.3.1 Motoriktest für vier- bis sechsjährige Kinder

The Motoriktest für vier- bis sechsjährige Kinder (MOT 4-6; Zimmer and Volkamer, 1987) is a product-orientated German assessment for MC development. It is age appropriate for preschool aged children as it is designed for 4-to-6-year old children, as it is believed that this age range requires its own pedagogical approaches. The short and clear score sheet makes it appropriate for use in an educational setting, especially considering that the test only takes

20-minutes per child. Additionally, it is regarded as a highly efficient assessment tool (Cools, et al., 2009), the test provides assessment of gross and fine motor skills, featuring 18 different skills assessments, including locomotive, object-control, stability and fine movement skills. Each skill is assessed on a three-point rating scale, from 0 of skill not mastered to 2 of skill mastered; total score refers to general fundamental movement skill performance which provides information on skill mastering. However, some skills are required to be completed barefoot, which may be a deterrent for some children. The MOT 4-6 it a validated MC assessment tool for preschoolers (Kambas, et al., 2012). Additionally, whilst data norms are provided, and separated by half-yearly age ranges, it is in older children. Moderate costs are associated with this assessment method (Cools, et al., 2009) and it is not widely used in British MC assessment. Therefore, this was not considered to be the most practical assessment tool, when other methods are considered more appropriate.

3.3.2 Movement Assessment Battery for Children

The Movement Assessment Battery for children (M-ABC; Henderson and Sugden, 1992) was devised for children aged 4-to-12-years, but this measurement tool was not specifically designed for younger ages, including preschoolers. The assessment tool consists of 32 items, which are subdivided into four age bands, and includes eight individual items measuring: manual dexterity, ball skills and balance skills. Each skill is assessed is rated on a 6-point rating scale, where 5 equals to the weakest performance, and 0 is the best performance. The quantitative and qualitative assessments provide a total impairment score. International normative data is widely available for preschoolers (Cools, et al., 2009). The M-ABC identifies and describes motor impairments within daily life. A positive of this assessment method is that skills assessed are age band specific to establish motor development patterns. The test takes up to 30-minutes per child. Moreover, the test was validated in 3-to-4-year old children, but not in 5-to-6-year old children, so when assessing the preschool age range, is impractical (Kokštejn, et al., 2018), and thus, not used within this thesis as the age range was between 3-to-6-years.

3.3.3 Peabody Developmental Motor Scales – Second Edition

The Peabody Developmental Motor Scales – Second Edition (PDMS-2; Folio and Fewell, 1983) is a process and product-orientated measure for MC specifically designed for early childhood (birth-to-6-years). The PDMS-2 assesses gross and fine movement skills that focuses on children with disabilities. The test takes 60-minutes to complete reflex, stationary, locomotive, object manipulation and fine movement skills, with a total of 249 items, but no short form is available for such a large assessment. The PDMS-2 is a standardised instrument to provide a total motor score, as well as differentiating between children that are typically developing and those that are delayed and disordered (Cools, et al., 2009). The assessment method has been shown to have low sensitivity in preschool aged children (Van Hartingsveldt, et al., 2005) and is designed for children with disabilities. This study was not purposefully looking at children with disabilities as an investigative group, so this assessment method would have limited application. The duration to complete and low sensitivity in preschoolers makes this assessment method unsuitable for this thesis.

3.3.4 Körperkoordinationstest für Kinder

The Körperkoordinationstest für Kinder (KTK; Kiphard and Shilling, 1974) is appropriate for typically developing children, as well as those with brain damage, behaviour problems or learning difficulties. Designed for children aged from 5-to-14-years old, the test takes up to 20 minutes to complete one child. The main form of MC assessment is through general dynamic balance skills. The KTK has been shown to have good reliability and validity in preschool populations (Cools, et al., 2009). Additionally, the normative data provided is sex-specific for boys and girls, as it is expected to see sex-differences, even at younger ages. However, the KTK is product-orientated assessment method that assess MC with one aspect of gross MC, not LC or OC skills. Therefore, as this test is not designed for children under the age of 5-years, which this thesis was directly assessing, and does not separate skills into LC and OC, so may miss nuanced MC information when gross MC is collected altogether, this assessment method was deemed impractical.

3.3.5 Maastrichtse Motoriek Test

The Maastrichtse Motoriek Test (MMT; Vles, et al., 2004) objectively measures qualitative aspects of movement skill patterns, alongside qualitative movement skill performance, in 25-minutes for children aged between 5-to-6-years. The test identifies between children with and without normal motor development, and the authors claim that children with a risk for Attention Deficit Hyperactivity Disorder (ADHD) can be detected early ages. The main aim is to objectify qualitative and quantitative aspects of movement. The MMT consists of 70 items, of which 34 measure quantitative and 36 measure qualitative aspects to MC. Children are scored via a 3-point scale, from 0-to-2. The MMT does have its limitations, as to assess qualitative aspects, the assessor must have strong observational skills. The qualitative observations included in overall MC provides a holistic view on strengths and weaknesses of each child, but there is an absence of LC skills recorded. So, when assessing overall MC of children with normal motor development, this assessment measures is not wholly appropriate (Cools, et al., 2009).

3.3.6 Bruininks-Oseretsky Test of Motor Proficiency

The Bruininks-Oseretsky Test of Motor Proficiency (BOTMP; Connolly and Michael, 1986) assesses both gross motor skills and fine movement skills. The test is suitable for individuals with mild-to-moderate motor coordination deficits aged between 4-to-21-years. The full test features 53 items divided into eight subsections and takes approximately 60 minutes to complete per child, for detailed MC assessment. However, there is a shortened version that has been shown to have high correlation with results from the long version, but it takes 20 minutes for the short version, and only 14 items. The BOTMP purpose was for identification of deficits in individual with light-to-moderate motor coordination problems. This assessment method is particularly appropriate for individuals with motor coordination deficits, and not for overviews of MC in preschool populations (Cools, et al., 2009). As such, it was not considered to be the most appropriate assessment method as this thesis wanted to assess normally developing children, not for children with varying levels of motor coordination problems.

3.3.7 Test of Gross Motor Development, Second Edition

The Test of Gross Motor Development – Second Edition (TGMD-2; Ulrich, 2000) assesses MC, summed from OC and LC skills. It can be used to assess MC in children aged from 3-to-10-years, which is when children develop through their most dramatic changes. Each item is performed twice and takes up to 20-minutes per child, and normative data is provided. A disadvantage of this assessment method is that the object-control items, such as the strike and overarm throw, may be inappropriate to use cross-culturally. This is a product-orientated test, designed to identify children who are significantly behind their peers. The TGMD-2 provides information on skill mastering, both above and beneath skill level. Also, instructions can be adapted to fit a child's individual needs whilst retaining the intent of the skill required to perform and encouragement is considered appropriate (Ulrich, 2000).

The TGMD-2 has been shown to be both reliable and valid in preschool populations (Simons, et al., 2008; Cools, et al., 2009; Valentini, 2012). Furthermore, it has been established that the TGMD-2 concepts provide a logical and appropriate approach to evaluating preschool children’s MC (Williams, et al., 2009). The TGMD-2 does require large quantities of equipment it is probably one of the most widely used assessment tools for MC in preschoolers (Cools, et al., 2009), particularly in British preschool populations, (Roscoe, et al., 2017). More recently, the TGMD – third edition (TGMD-3; Ulrich, 2013) has been developed from the TGMD-2, but a number of the skills have remained the same as the previous version. Differences between the TGMD-2 and -3 are that leaping has been replaced with skipping, the underarm roll has been replaced with the underarm throw, and the forehand strike has been added in the updated version. Not explicitly measuring stability skills separately could be deemed a limitation, however Ulrich (2000) suggests that in order to perform the skills in the TGMD-2, stability is needed, and so, if stability is poor, then it will be likely that MC scores will be poor.

Additional MC assessments have been devised using the TGMD-2. The Children’s Activity and Movement in Preschool Study (CHAMPS) devised a tool for use in diverse field-based settings that are typical of large, multifaceted epidemiological studies (Williams, et al., 2009) called the CHAMPS Motor Skills Protocol (CMSP; Williams, et al., 2009). However, some protocol steps were different. In the TGMD-2, each performance of the skill is performed twice after one verbal and physical demonstration, with an additional demonstration if children fail to understand the task. But the CMSP protocol involves two demonstrations of the skill towards the children and then in the direction the children would be performing. In preschool ages, some children may require instructions to be repeated to fully understand what they are expected to do, especially considering that the Early Years Statutory Framework (Department of Education, 2017) used as the curriculum for preschool aged children in childcare provisions encourages and advises that children may require additionally instructions or demonstrations when understanding instructions. Therefore, whilst the CMSP has been validated in preschoolers, (Williams, et al., 2009) it was decided that the TGMD-2 was more in keeping with the instruction delivery the preschool children were regularly exposed to, as well as being more widely used in literature.

3.4 Perceived Motor Competence

Self-concept is a generic term as an evaluative indicator of self, often referred to as an individual's assessment of their own competence compared to others (Gallahue, et al., 2012). Terms such as "self-confidence", "self-efficacy", "perceived ability" and "perceived motor competence" all describe one's perceived capabilities to complete certain standards of skill performance (Feltz, 2007). As a consequence, there are a variety of tools available to assess aspects of perceived competence.

3.4.1 Physical Self-Perception Profile

The Physical Self-Perception Profile (PSPP; Fox and Corbin, 1989) incorporates five categories to establish self-perceptions, including "sporting competence", "physical strength", "physical conditioning", "body attractiveness" and "physical self-worth". The PSPP looks at the individual's views of themselves, not specifically at performance in MC skills. Within this thesis, perception of "body attractiveness" is not important when assessing perceived MC. The PSPP has been referred to as a useful assessment measure of physical self-perception in older children and adults but is not age appropriate for preschool aged children (Ekelund, et al., 1997) and has not been used or validated in early childhood populations. Furthermore, this assessment measure is not directly comparable to any actual MC assessment methods.

3.4.2 Pictorial Scale of Perceived Competence and Social Acceptance for Young Children

The Pictorial Scale of Perceived Competence and Social Acceptance for Young Children (PSPCSA; Harter and Pike, 1984) consists of two versions, one for preschoolers and another for 5-to-7-year olds. The assessment measure includes components assessing for "cognitive competence", "physical competence", "physical appearance", "social appearance" and "behavioural conduct", additionally it also provides a measure of general self-worth. The pictorial scale assesses "physical competence" as typical behaviours in childhood, such as swinging on a swing. However, this assessment method has not shown to be validated in preschool children (Fantuzzo, et al., 1996), and therefore not appropriate for use in this age group.

3.4.3 Pictorial Scale of Perceived Movement Skill Competence

The Pictorial Scale of Perceived Movement Skill Competence (PSMC; Barnett, et al., 2015) was initially developed for the purpose of assessing MC competence perceptions among children under 8-years old. It is the first tool for young children to assess perceptions of movement skill competence. The PMSC assesses 12 perceived MC skills, which were incorporated from the TGMD-2 (Ulrich, 2000), with additional active play skills including swimming, board paddling, riding a bike, scootering, inline skating and climbing (Barnett, et al., 2015).

Barnett and colleagues (2015) report that the 18-itemscale to investigate children's perceived movement competence is acceptable and validated in young children, as do other validation studies (Estevan, et al., 2016; Chan, et al., 2018;

Slykerman, et al., 2018; Valentini, et al., 2018; Venetsanou, et al., 2018). Furthermore, the alignment to TGMD-2 as a measure of MC, makes this perceived MC assessment particularly appealing in preschoolers.

4 General Methods

4.1 Overview

It is important to have accurate, valid and reliable results of physical activity (PA), motor competence (MC) and weight status in preschoolers to produce outcomes that could appropriately and effectively influence a policy change in PA and physical development guidelines. Within this section, the methods used to collect the data for each variable being assessed in the following experimental chapters will be discussed.

4.2 Recruitment

The sample was a convenience sample of schools, preschools and childcare settings that agreed to participate. The preschools were chosen as they were from the Coventry and surrounding areas. In addition, it was also ensured that none of the schools had a specialised intervention or specific focus in place at the time of testing in relation to PA or MC. A total of six preschools or nurseries were approached to participate in the study, with five agreeing to participate. A total of 196 children were approached to participate in baseline assessment, with 177 agreeing to participate, and 166 completing sufficient PA data and MC assessments. At follow-up 166 with complete data at baseline were contacted to participate, with 92 agreeing to participate.

The Index of Multiple Deprivation (IMD) is measures relative levels of deprevation of small neighbourhoods in England based on a ranking scale, which then are divided into ten equal groups to identify the top 10% most and least deprevied areas (National Statistics, 2019). Coventry's small neighbourhoods range from being in the 10% most deprived (27 out of 181) to being in the 10% least deprived (9 out of 181). The average IMD decile of Coventry and surrounding areas is 4.71, meaning that overall Coventry in the middle of being the most and least deprived. Based on the postcodes of the schools and preschools that were included in the thesis, IMD decile ranged from 2-to-6, with an average IMD decile of 4, which means the schools were in the 40% most deprived neighbourhoods (National Statistics, 2019).

A letter was sent to the preschools to explain in more detail about the description and details on the research project. If the preschools agreed with the project a meeting was arranged with a member of staff to discuss further questions. Once the preschool had accepted to participate fully, arrangements for a timetable that suited the preschool was arranged and the distribution of the informed consent form was sent to the children and their parents or guardians of all children in the preschool age range of 3-to-5-years at the time of testing. (Appendix 1: Sample Informed Consent; page 200). At the end of the testing session, each child was sent home with a reminder sheet for the parents to explain the procedure of how to put on the accelerometers if removed and the length of time they would be wearing them for. A year later, each child's parent was contacted to discuss the possibility of retesting. All recruitment processes were repeated, including letter detailing the project, consent forms, and reminder sheets.

4.3 Ethics

Institutional ethical approval was obtained from Coventry University's Ethics Committee (P31810, 16 February 2015; P37708, 14th December 2015; Ethics Committee Coventry University) prior to baseline and follow-up data collection, . Informed consent and information sheets were sent to each of the parents of each participating preschool. 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.

Children gave their assent to participate in the research and were also reminded that they did not have to participate if they did not wish to and were assured that all information was confidential and that their names would not be used. Children were identified numerically for anonymity. In each session of data collection children wore a sticker or a coloured overhead bib with a number on with their number on. This was done so individuals could be identified on camera anonymously. As an additional benefit, this kept the children in the correct numerical order making data analysis easier.

4.4 Organisation of data collection sessions

Data collection took place on site at each provision, between the months of January and May. At the beginning of each of the sessions anthropometric data, as stature and mass, were recorded. There was one researcher at each station and each child would visit each station individually, this enabled discretion of the results. Wherever possible the same researcher was on the same station each week to keep the results consistent.

The format of data collection began with anthropometric data collection, followed by perceived MC assessments at follow-up only, then MC measures and finally PA assessment. Perceived MC was assessed in a one-to-one scenario. Next, the children were put into manageable groups of no more than 10 children to complete all MC assessments. Following this, the accelerometers were put on each of the children who assented to wear one.

Date of birth was obtained from the parents. Anthropometric measures were carried out in a space outside their classroom to minimise impact to the teaching day. Children wore their school uniform or PE clothes for assessments.

4.5 Anthropometric measures

4.5.1 Stature

Height was recorded to the nearest millimetre 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 up straight and have their chin parallel to the ground, looking forward (Frankfort horizontal plane; Thompson et al., 2009). The researcher would correct their position if required with the 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).

4.5.2 Body Mass

With shoeless feet, children stepped onto electronic scales (SECA, Instruments, Ltd, Germany, model: SECA877) to assess body mass to the nearest 0.1 kg. Children's head was up, looking forward and their weight evenly 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).

4.5.3 BMI

BMI was calculated as kg/m^2. To establish weight status age and sex-specific cut points were used (Cole, et al., 2000). Children were classed as overweight if they were in the 85^{th} centile and obese if in the 95^{th} centile (Cole et al., 2000). Weight status was used as a variable in each study.

4.6 Motor Competence Assessment

Motor competence (MC) was assessed using the Test of Gross Motor Development 2 (TGMD-2), in accordance with guidelines provided by Ulrich (2000). The TGMD-2 is a norm-referenced measure of common motor skills that develop early in life and assessed by a process-orientated checklist.

It is comprised of two subtests for gross motor development – "Locomotor" and "Object Control" – both of which have six skills that assess a different aspect of gross motor development. Locomotor skills include: run, gallop, hop, leap, horizontal jump and slide. Object Control skills include striking a ball, stationary dribble, kick, catch, overhand throw and underarm roll. Each of the skills includes several behavioural components that are presented as a performance criterion. If the child performs the criterion correctly, the researcher will record a '1'. If the child does not perform the criterion correctly, the researcher will record a '0'. No partial scores are allowed. If a child does not wish to participate in the skill, a 'Did not participate' is recorded. Each subtest includes 24 performance criteria. Each subtest has a total raw score attained by summing the scores for the related skills. Each skill was verbally explained and physically demonstrated once to the child before their performance, with an additionally demonstration if children failed to understand the task. Following this, the child would perform the skill twice in view of a camera. The maximum score is 96.

The camera was set up on the sagittal plane following guidelines by Knudson (2007). A 10 m marked distance was provided by cones for the locomotor skills. The children were asked to perform each skill between the cones. Run, gallop, and leap were performed traveling from one cone to the other, to count as one attempt. Hopping and jumping were performed in view of the camera, and sliding was performed facing the camera between each cone. For assessment of the object-control skills, a cone was placed in a line with the camera. Each child would stand by the cone and perform the object-control skills then switch with another child. For the skills to be performed, specific equipment was used as suggested by Ulrich (2000). Each MC skill was 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 analysed using this software, so videos could be slowed down and replayed.

The process orientated checklist was used to determine each of the children's motor competence as it accurately identifies the specific aspects of the movement, such as the technique and position of different body segments (Ulrich, 2000). Two researchers experienced in the assessment of children's movement skills analysed the MC videos. Congruent with prior research (Barnett, et al., 2014), training was considered complete when each observer's scores for the two trials differed by no more than one unit from the instructor score for each skill (>80% agreement). Inter- and intra-rater reliability analysis was performed for all LC and OC between the two researchers. For LC and OC, inter-rater reliability was 90.0% and 81.0% respectively, and intra-rater reliability was 93.0% and 81.0%, respectively, demonstrating good reliability (Jones, et al., 2010).

4.6.1 Locomotor Skills

Locomotor subtest measures are gross motor skills that require fluid coordinated movements of the body as the child moves in one direction and skills that are involved in moving the centre of gravity from one point to another. Running is the ability to advance steadily by springing steps so that both feet leave the floor for an instant with each stride. Galloping is the ability to perform a fast, natural three beat gait. Hopping is the ability to hop a minimum distance on each foot. Leaping is the ability to perform all skills associated with leaping over an object. The horizontal jump is the ability to perform a horizontal jump from a standing position. Sliding is the ability to slide in a straight line from one point to another whilst facing sideways.

Each of the locomotor skills was performed over a 10 m distance that was marked by two cones. Although the TGMD-2 states that the largest distance for the skills should be completed over distances of 20 m, this was not always possible due to the size of the testing area. Therefore, the test was adapted to a minimum of 10 m assessment view from the camera.

Running was performed over a minimum of 10 m with space at the end for a safe stopping distance and the child was encouraged to run as fast as they could. Galloping was performed between two 10 m distanced cones. Hopping was performed between the 10 m cones, on each leg in view of the camera, with the leg being hopped closest to the camera. Leaping was performed with a bean bag in between the two cones that were spaced 10 m apart. The children were told to run to the beanbag and leap over the beanbag. Horizontal jumping contained three jumps. The child was told to start on one of the cones and jump in the direction of the other cone 10 m away and to jump as far as they could for each jump. Sliding was performed with the child sliding from one cone to another and back and repeated. The body was turned sideways, to face the camera.

4.6.2 Object-Control Skills

Object control skills are gross motor skills that demonstrate efficient throwing, striking and catching movements, and are involved in projecting and receiving objects. Each of the object-control skills was completed by a cone, in view of the camera, on the sagittal plane. Striking is the ability to strike a ball with a plastic bat. A stationary dribble is the ability to dribble a basketball a minimum of three times with the dominant hand before catching it with both hands and without moving their feet. Catching is the ability to catch a ball that has been tossed underhand. Kicking is the ability to kick a stationary ball with the preferred foot. An overhand throw is the ability to throw a ball at a point on a wall with the preferred hand. An underarm roll is the ability to roll a ball with the preferred hand.

During the strike a 4-inch light weight plastic bat and a foam tennis ball were used, in accordance with TGMD-2 guidelines (Ulrich, 2000). The ball placed on a batting tee at the child's belt height, then the child was told to hit the ball hard. An 8-inch plastic ball was used for the stationary dribble. The child was instructed the bounce the ball on the as many times a without moving their feet using one hand, and to stop by catching the ball. The researcher would then count how many and instruct the child to stop if they completed the recommended four bounces. For the catch, the researcher stood 5 m from the child, and threw an underarm toss with a foam tennis ball to the child with a slight arc aiming for the chest. The child was instructed to catch with both hands. Only tosses that were between the child's shoulders and belt were counted as successful throws. An 8-inch plastic ball was used with the kicking. The child stood 5 m away from the ball which was balancing on the beanbag. When they were ready, the child would run up to the ball and kick the ball hard. For the overarm throw, the researcher stood 6 m away from the child and instructed the child to throw the ball at the researcher as hard as they could. For the overarm throw a foam tennis ball was used. For the roll, the researcher stood 5 m away from the child and instructed the child to roll the ball hard at the researcher.

4.7 <u>Physical Activity Assessment</u>

Habitual PA was measured using GENEActiv accelerometers (GENEActiv ActiveInsights, Cambridge, UK). The children were told to wear the accelerometers when they were awake, and that they could be removed at bedtime, bath time and if the child went swimming. The accelerometers were worn for four consecutive days, including two weekend days. Four consecutive days is sufficient time to capture PA (Trost, et al., 2005) and has been used previously in British preschool aged children (Roscoe, et al., 2017; Roscoe, et al., 2019). The accelerometers were handed out on a Thursday by the researcher and collected by the researcher on the following Tuesday for a full four days of data. Each class and each school kept to this same template to ensure consistency. Children who did not have all four days of analysis or did not have ≥600 minutes of PA data per day were not included in the analysis, as it was deemed there was not sufficient PA data in accordance with previous research (Hinkley, et al., 2012; Cain, et al., 2013; Hislop, et al., 2013).

GENEActiv accelerometers have been shown to be both reliable and valid measure of PA in adults and children (Esliger, et al., 2011; Phillips, et al., 2013). The GENEActiv accelerometers were set to record at 100 Hz and 60 seconds epochs. The accelerometers were calibrated via connection to specific computer software, (GENEActiv PC Software 2.2). In a recent review (Migueles, et al., 2017), there was no reported influence of epoch length on accelerometer output in preschoolers. Upon completion of the protocol, each participant's accelerometer data was downloaded and stored on a computer.

Using the GENEActiv post-processing software, the raw 100 Hz triaxial GENEActiv data were summed into a signal magnitude vector (gravity subtracted) expressed in 60 second epochs. The accelerometer counts were coded into sedentary, light, moderate and vigorous intensities using previously validated cut-points for the dominant hand in preschool aged children (Roscoe, et al., 2017). These 60 seconds epochs were then used to calculate how much time these children spent in the ≥60 minutes of MVPA and ≥180 minutes of PA per day to meet the current recommendations.

4.8 Children's perception of skill ability assessment

The pictorial scale of perceived movement skills competence for young children (PSMC; Barnett, et al., 2015) based on the TGMD-2 (Ulrich, 2000) was used to assess perceived MC 24-to-48 hours before MC was assessed. Assessment of perceived MC was completed in accordance with PSMC guidelines (Barnett, et al., 2015).

The PSMC uses a four-point Likert scale response variable (range 1-to-4). The PSMC is a reliable and valid measure of perceived MC in young children (aged 5-to-7 years; Barnett, et al., 2015; Valentini, et al., 2018; Vanetsanou, et al., 2018). The children completed the perceived MC assessment one-on-one with a trained researcher with males and females receiving specific booklets (Barnett, et al., 2015).

For each skill, children were shown two, sex-specific illustrations of a child performing the skill competently or incompetently and were then asked, “This child is pretty good at [skill], this child is not so good at [skill]; which child is most like you?” Children when then asked to select a descriptive for further detail; for the competent illustration 4 – really good, 3 – pretty good, 2 – sort of good, or 1 – not so good. Possible scores for perceived MC ranged from 12-to-48.

4.9 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 for all assessments in each study. The individual statistical tests for the individual studies are reported in each of the experimental study chapters. All figures were created using Microsoft Excel 2010.

Thesis Map Study One

	Aims
Study One: Relationships between motor competence, physical activity and obesity in British preschool aged children	• To investigate associations between weight status, physical activity (PA) and motor competence (MC), as proposed by the Stodden, et al., (2008) model. • To identify current PA levels and compliance to PA recommendations.
Study Two: Does perception of motor competence mediate associations between motor competence and physical activity in preschool children?	• To examine if associations between PA and actual motor competence in British preschool children are mediated by perceived MC, as suggested in the Stodden, et al., (2008) model.
Study Three: Moderate-to-vigorous physical activity is more important than motor competence in maintaining healthy weight status in British preschool children.	• To identify the strongest contributor to current BMI, from previous BMI, and previous and current PA and MC. • To identify the strongest contributor to current PA, from previous PA, and previous and current BMI and MC. • To identify the strongest contributor to current MC, from previous MC, and previous and current BMI and PA.

5 Study One: Relationships between motor competence, physical activity and obesity in British preschool aged children

5.1 Abstract

Introduction: It is reported that children are not sufficiently active (De Bock, et al., 2014). Being proficient in movement skills may have positive associations with being more active (Stodden, et al., 2008). **Aims:** This cross-sectional study aimed to examine associations between motor competence, physical activity, and obesity in British children aged three to five years. **Methodology:** Weight status was classified with body mass index (BMI), calculated as kg/m^2. Motor competence (MC) was assessed using the TGMD-2. Physical activity (PA) was assessed using triaxial wrist-worn accelerometers. Children were assessed on compliance to current PA recommendations of ≥180 minutes of total PA (TPA) and ≥60 minutes of moderate-to-vigorous PA (MVPA) for health benefits. Associations were explored with Pearson's product moments. Differences between weight status, and sex groups were explored with independent t-tests and chi-squared analysis. **Results:** A total of 166 children (55% males; 4.28 ± 0.74 years) completed MC and PA assessments. Associations were found between PA and MC (TPA and overall MC, TPA and object-control MC (OC), MVPA and overall MC, and MVPA and OC). LC was significantly higher in children who completed TPA recommendations *(P* = 0.050) than those who did not, and OC was significantly higher in children than completed MVPA recommendations *(P* = 0.003). **Conclusions:** This study suggests that good MC is an important correlate of children meeting PA guidelines for health when using population and age validated PA cut-points.

5.2 Introduction

Childhood obesity is a serious public health challenge of the 21st century, with enduring adverse consequences for health outcomes. Over 42 million under-fives are estimated to be overweight or obese (Ng, et al., 2014), and current predictions are 70 million children will be overweight or obese by 2025 (Ng, et al., 2014). Elevated body mass index (BMI) is a major risk factor for noncommunicable diseases such as cardiovascular disease, diabetes, and some cancers (WHO, 2010). Overweight children have an increased risk of adulthood obesity, premature death, and disabilities in adulthood, resulting in prevention of childhood obesity being considered as a public health priority (WHO, 2010).

Overweight children obtain less physical activity (PA) than healthy weight peers (Stodden, et al., 2008), and therefore improving PA participation in is seen as a key preventative focus (Warburton, et al., 2006). Current PA guidelines (Department of Health, 2018) recommend children under 5-years complete ≥180 minutes of total PA (TPA), including light and moderate-to-vigorous PA (MVPA), and children aged 4-to-17 years complete ≥60 minutes MVPA per day. MVPA has been shown to play a key role in health, particularly when related to weight status (O’Dwyer, et al., 2011; Fairclough, et al., 2017), however, it is widely reported that children under five years are not sufficiently active (Janz, et al., 2010; De Bock, et al., 2011; O’Dwyer, et al., 2011; 2013, 2014).

Studies in American and German children using uniaxial accelerometery have reported that children are not meeting either PA guidelines (Janz, et al., 2010; DeBock, et al., 2011). British preschoolers have similarly been reported to not meet current PA guidelines, although weight status is reported to not influence the amount of PA undertaken by preschoolers (O’Dwyer, et al., 2011; 2013; 2014). Prior work has reported that British preschoolers achieved on average 38.6 minutes of MVPA and 96.7 minutes of TPA per day (O’Dwyer, et al., 2011). In two related studies, examining preschoolers from the same geographical area as O’Dwyer , et al., (2011), similar magnitudes of PA have been reported (O’Dwyer, et al., 2013, 2014). No significant sex or weight status differences between MVPA completion rates were reported in this prior work (O’Dwyer, et al., 2011; 2013; 2014). However, the PA cut-points used by O’Dwyer, et al., (2011; 2013; 2014), were validated in American preschool children (Sirard, et al., 2004). Use of cut-points derived from American preschoolers to assess PA in a British population may not fully capture the PA behaviour of children, due to the different social and economic environments in which PA takes place in the U.S. compared to the UK. Conversely, other research has reported that 95.6% of British preschoolers completed TPA recommendations for health. Similar to the aforementioned studies by O'Dwyer, et al., (2011; 2013; 2014), Barber, et al., (2015) used cut points which were validated in American preschoolers (Pate, et al., 2006) despite investigating children from Bradford, UK (Barber, et al., 2015). Preschool-based approaches that decrease sedentary behaviour and increase PA may aid in combating the epidemic of juvenile obesity. However, to avoid geographical and demographical bias on PA, using British validated PA cut-points designed for British children is crucial to better quantify PA, and would establish valid current PA patterns. Furthermore, to explore relationships between variables longitudinally, cross-sectional baseline data must be established to provide comparative information.

According to Stodden, et al., (2008), motor competence (MC) is a precursor to PA and learning to move is necessary for PA participation. Fundamental motor skills (FMS) develop during childhood, form the foundation for lifelong PA, and are conceptualized as comprising locomotor skills and object-control skills (Clark, et al., 2002). Locomotor MC (LC) involves proficiency in moving within space, such as running, galloping, skipping, hopping, sliding, and leaping, and object-control MC (OC) involves manipulating objects, to throw, catch, bounce, kick, strike, and roll (Haywood and Getchell, 2009). There are relatively few studies which report the levels of MC in British preschoolers, although one study has concluded that the levels of MC are low in this population (Foulkes, et al., 2015).

Work in Australia has reported that overall preschoolers were not sufficiently active for health, and females are more proficient in LC than males (Cliff, et al., 2009). The aforementioned work (Cliff, et al., 2009) also reported that the different aspects of MC were related to PA in differing ways; OC is more strongly associated with MVPA in males, compared to LC, which is more strongly associated with MVPA in females compared to males. For urbanised British preschoolers, weekday MPA was positively associated with LC (P = 0.016), weekend MVPA was positively associated with total MC (P = 0.034) and OC (P = 0.028). Weekend TPA was positively associated with OC (P = 0.008). Males were also significantly more active in MVPA than females at weekdays (P = 0.007) and weekends (P = 0.012); and weekday TPA (P = 0.040); and more proficient in OC skills (P = 0.018; Foweather, et al., 2015).

Preschoolers have consistently been identified as undertaking insufficient PA for health (O'Dwyer, et al., 2011; Janz, et al., 2010; De Bock, et al., 2011; O'Dwyer, et al., 2013; O'Dwyer, et al., 2014). Associations between PA and MC have been identified in preschoolers (Cliff, et al., 2009; Foweather, et al., 2015), but establishing current PA levels and the extent to which British preschoolers complete the recommended amount of PA, with the use of objective and validated measures, and alongside objective MC assessment methods, has yet to be completed. The aim of this study was to examine associations between MC and objectively measured PA, and relations to weight status in British preschoolers.

5.3 Methods

5.3.1 Participants

Following institutional ethics approval (P31810; 16 February 2015; Ethics Committee Coventry University) and informed parental consent, a convenience sample of 177 healthy preschool aged participants (males 54.1%; 4.28 ± 0.74 years) from state funded childcare provisions within the Coventry and Warwickshire area was recruited. Schools and preschools that were recruited were from varied socioeconomic backgrounds and participants all attended school or preschool for a minimum of 15 hours per week. Data collection occurred between January to May in 2015 during childcare hours. Children were included in the analysis if both MC assessments and PA assessments were completed.

5.3.2 Procedures

5.3.2.1 Anthropometric Measures

Body mass (to the nearest 0.1 kg) and stature (to the nearest 0.1 cm) were measured objectively by trained researchers using digital scales (SECA Instruments, Ltd, Hamburg, Germany) and a portable stadiometer (SECA Instruments, Ltd, Hamburg, Germany). Body mass index (BMI, kg/m^2) classified weight status as either healthy (HW: 1), or overweight or obese (OW: 2), based on International Obesity Task Force cut-points (Cole, et al., 2000).

5.3.2.2 Motor Competence

Motor competence (MC) was assessed using the Test of Gross Motor Development-2 (TGMD-2; Ulrich, 2000). Six locomotor (run, jump, hop, leap, gallop, and slide) and six object-control (catch, throw, kick, bounce, strike, and roll) skills were assessed. Each skill comprised three to five components, and skill mastery requires each component to be present. Video recordings of each skill (Sony video camera, Sony, UK) were edited into single-film clips of individual skills with Quintic Biomechanics analysis software v21 (Quintic Consultancy Ltd, Sutton Coldfield, UK). Children completed the TGMD-2 in school facilities. Each skill was described and demonstrated once by a researcher, and each child performed each skill twice. During analysis, each skill was marked by its individual components as successful (marked as 1) or unsuccessful (marked as 0) and totalled with both trials to give a total skill score. Scores were summed from two trials to create a total overall raw score (scored 0-to-96) following test administration guidelines (Ulrich, 2000). The skills identified as LC and OC were grouped together according to subtest scores (scored 0-to-48) and the summing of these gave an overall MC score. All analyses were completed by two trained researchers. Intra- and inter-reliability was established for MC assessments within 15% of the final data set. Intra-rater reliability across LC and OC showed 93.0%, and 81.0% agreement, respectively. Inter-rater reliability showed 90.0%, and 81.0% agreement across LC and OC, respectively.

5.3.2.3 Physical Activity

Physical activity (PA) was determined using wrist worn triaxial accelerometery (GENEActiv ActiveInsights, Cambridge, UK). Accelerometers were worn for four consecutive days on the child's dominant hand (Esliger, et al., 2011) during all waking hours, except for water based activities to prevent skin irritation when drying. A sampling frequency of 100Hz was employed with data collected in sixty second epochs. The accelerometer in question has demonstrated acceptable reliability and validity as a PA measure in children (Esliger, et al., 2011; Phillips, et al., 2013). Valid wear time was defined as a minimum of four consecutive days with two weekend days, with at least ≥600 minutes of data recorded between 6 am and 10 pm. Non-wear time was defined as 20-minute windows of consecutive zero or non-zero counts (Choi, et al., 2011).

PA was classified as sedentary, light, or moderate-to-vigorous in nature using the Roscoe, et al., (2017) cut-points, as these are the only validated cut-points for British preschool aged children. This data was then used to determine children who did and did not meet the TPA recommendations, the MVPA recommendations, and the combined recommendations of both TPA and MVPA (WHO, 2010). For assessment of TPA ≥180 minutes a day, MVPA ≥60 minutes for zero-to-five-year olds is considered appropriate (Warburton, et al., 2006; WHO, 2010; Department of Health, 2018), and children were classified as sufficiently active if this requirement was met.

5.3.3 Statistical Analysis

Descriptive statistics were calculated by all sex groups and weight status and reported as means (± SD), seen in Table 5.1. Percentages of children that completed each PA recommendation were calculated. Associations between BMI, MC, and PA, which were examined via Pearson's product moments correlations and sex and weight-status differences were examined by independent *t*-tests. Chi-squared analysis was used to identify differences in MC between those who did and did not meet PA recommendations. A series of analysis of covariance (ANCOVA) compared MC scores between children who did and did not complete PA recommendations, whilst controlling for BMI. Data was analysed using IBM SPSS Statistics Version 21 (IBM Corporation, New York, NY, USA), with statistical significance set at $P < 0.05$.

5.4 Results

A total of 94% ($n = 166$) of the original 177 children were included, as they had complete MC results and sufficient PA data and were therefore included in final analysis. Within the remaining 166 participants, 60.5% were Caucasian, 22.0% were South-East Asian, and 14.7% were black. 88.0% were classified as healthy weight, 8.4% were classified as overweight and 4.1% were considered obese.

Table 5.1 Mean (±SD) of BMI, physical activity and motor competence

	All *n* = 166	Males *n* = 91	Females *n* = 75	HW *n* = 146 53% male	OW *n* = 20 75% male
Age (years)	4.28 ± 0.74	4.34 ± 0.74	4.21 ± 0.73	4.27 ± 0.75	4.33 ± 0.64
BMI (kg/m^2)	16.11 ± 1.65	16.27 ± 1.78	15.93 ± 1.47	15.65 ± 1.11	19.09 ± 1.42
TPA (mins)	279.65 ± 118.33	289.95 ± 119.99	266.90 ± 116.00	279.36 ± 116.48	282.07 ± 137.77
MVPA (mins)	238.69 ± 101.87	248.06 ± 104.85	227.10 ± 97.71	239.18 ± 99.74	234.59 ± 122.61
Overall MC (out of 96)	45.73 ± 12.07	45.73 ± 13.01	45.88 ± 10.75	43.46 ± 12.19	44.29 ± 11.59
LC (out of 48)	26.80 ± 7.60	26.10 ± 8.01	27.80 ± 6.95	26.80 ± 7.83	26.82 ± 6.13
OC (out of 48)	18.93 ± 8.30	19.53 ± 9.04	18.08 ± 7.13	19.16 ± 8.15	17.47 ± 9.29
% that complete TPA recommendations	80.30	82.19	77.97	61.69	45.83
% that complete MVPA recommendations	89.39	86.30	93.22	68.83	50.00
% that complete combined PA recommendations	75.76	75.34	76.27	58.44	41.67

Note: MC, motor competence; LC, locomotor motor competence; OC, object-control motor competence; PA, physical activity; TPA, total PA; MVPA, moderate-to-vigorous PA; BMI, body mass index; HW, healthy weight; OW, overweight or obese.

[a] Sex-differences identified as significant at the 0.05 level (2-tailed).
[b] Sex-differences identified as significant at the 0.01 level (2-tailed).
[c] Weight status differences identified as significant at the 0.05 level (2-tailed).
[d] Weight Status differences identified as significant at the 0.01 level (2-tailed).

Table 5.2: Correlations of BMI, physical activity and motor competence

	BMI	TPA	MVPA	Overall MC	LC	OC
BMI		R = 0.018	R = 0.012	R = −0.043	R = −0.045	R = −0.022
TPA			R = 0.733 [b]	R = 0.402 [b]	R = 0.170	R = 0.386 [b]
MVPA				R = 0.376 [b]	R = 0.152	R = 0.367 [b]
Overall MC					R = 0.734 [b]	R = 0.783 [b]
LC						R = 0.152
OC						

Note: MC, motor competence; LC, locomotor motor competence; OC, object-control motor competence.
[a] Correlation is significant at the 0.05 level (2-tailed).
[b] Correlation is significant at the 0.01 level (2-tailed).

Table 5.3: Mean (± SD) MC in children who met and did not meet PA recommendations

	TPA Recommendations		MVPA Recommendations		Combined PA Recommendations	
	Met	**Not Met**	**Met**	**Not Met**	**Met**	**Not Met**
MC	45.99 ± 11.16 [b]	38.47 ± 10.55	45.17 ± 10.89 [a]	35.14 ± 13.98	45.88 ± 11.20 [a]	39.20 ± 10.77
LC	26.70 ± 6.86 [a]	23.37 ± 7.52	26.00 ± 7.19	25.86 ± 6.34	26.65 ± 6.90	23.70 ± 7.47
OC	19.29 ± 8.35	15.11 ± 9.53	19.17 ± 8.09 [b]	9.29 ± 11.31	19.23 ± 8.40	15.50 ± 9.44

Note: MC, motor competence; LC, locomotor competence; OC, object-control competence.
Differences are controlling for BMI
[a] Correlation is significant at the 0.05 level (2-tailed).
[b] Correlation is significant at the 0.01 level (2-tailed).

Children were sufficiently active with 279.65 ± 118.23 minutes of TPA and 238.69 ± 101.87 minutes of MVPA. Over 80% of children met TPA recommendations of ≥180 minutes of TPA, over 89% met ≥60 minutes MVPA recommendations, and over 75% completed both TPA and MVPA recommendations. Both LC and OC scores were considered to be average. Males were more active (TPA and MVPA) and were more proficient in OC than females and were more likely to complete TPA recommendations, but less likely to complete MVPA recommendations. Overweight children had higher TPA and were more capable in overall MC and LC skills. Healthy weight children were more likely to complete TPA, MVPA, and combined PA recommendations.

Moderate significant associations were found between PA and MC (Table 5.2). Specifically, between TPA and overall MC *(P* = 0.001), TPA and OC *(P* = 0.001), MVPA and overall MC *(P* = 0.001), and MVPA and OC *(P* = 0.001).

No significant sex-differences were identified in TPA *(P* = 0.267), MVPA *(P* = 0.718), overall MC *(P* = 0.908), LC *(P* = 0.221), and OC *(P* = 0.342). Similarly, there were no significant differences in the number of males compared to females that completed TPA recommendations *(P* = 0.544), completed MVPA recommendations *(P* = 0.199), or completed combined PA recommendations *(P* = 0.901). There were no significant weight status differences in TPA *(P* = 0.936), MVPA *(P* = 0.886), overall MC *(P* = 0.599), LC *(P* = 0.991), and OC *(P* = 0.438). Additionally, there were no differences in the number of children that completed TPA recommendations *(P* = 0.836), completed MVPA recommendations *(P* = 0.636), and completed combined PA recommendations *(P* = 0.689), between healthy weight and overweight children.

When controlling for BMI, overall MC was significantly higher in children who completed TPA recommendations *(P* = 0.008), who completed MVPA recommendations *(P* = 0.014), and who completed combined PA recommendations *(P* = 0.014), than children who did not (see Table 5.3). Furthermore, LC was significantly higher in children who completed TPA recommendations *(P* = 0.050) than those who did not, and OC was significantly higher in children than completed MVPA recommendations *(P* = 0.003).

5.5 Discussion

This study examined associations between MC, objectively measured PA, and weight status, in British preschoolers. The current study also examined the proportion of children who completed the recommended levels of total PA and MVPA for health. Within this cohort, >80% of children achieved TPA recommendations, >89% achieved MVPA recommendations, and >75% achieved both PA recommendations. This suggests that in this sample, children were sufficiently active for health. In agreement with previous literature, there were no significant sex-differences in TPA, MVPA, or combined PA recommendation compliance (O'Dwyer, et al., 2013). However, it is important to note that males were more likely to complete TPA recommendations and females were more likely to complete MVPA recommendations.

Positive associations between TPA and overall MC, TPA and OC, MVPA and overall MC, and MVPA and OC, were identified consistent with previous literature (Stodden, et al., 2008; Cliff, et al., 2009; Foweather, et al., 2015). There were no significant sex-differences identified in overall MC, LC, or OC, which is congruent with previous literature (Cliff, et al., 2009) but contradictory to other literature (Foulkes, et al., 2015; Foweather, et al., 2015). The lack of significant sex-differences can be explained by the age and stage of the cohort, as they are in early childhood and MC is yet to mature (Stodden, et al., 2008). Additionally, there were no significant differences in MC between overweight and normal weight children. Stodden, et al., (2008) suggests that MC is a precursor to PA; as there are no sex or weight status differences in PA, as expected, MC was similar. No identified sex-differences was unsurprising given the children's age, as these children are prepubescent, so any differences are unlikely to be from sex (Malina, 2014), and are more likely to be due to other external influences, like parental influence or environmental factors.

This is the first study to quantify PA levels undertaken by British preschoolers using cut-points validated in British preschool aged children (Roscoe, et al., 2017). This is coupled with use of an objective and valid method for assessing MC (Ulrich, 2000). This study therefore addresses limitations of prior studies examining the same topic in British preschoolers (O'Dwyer, et al., 2011; 2013; 2014). In the current study, children who completed PA (TPA, MVPA, and combined) recommendations for health-related benefits were significantly more proficient in overall MC. Children that achieved ≥180 minutes of any PA per day had significantly better LC scores than those that did not. Additionally, children that accomplished ≥60 minutes of MVPA per day had significantly better OC scores. These findings provide a potential strategy for intervention to increase PA or MC in children, and ultimately to reduce childhood obesity. To improve completion of ≥180 minutes of TPA for health, improving LC may help, and improving OC should improve the completion of ≥60 minutes of MVPA for health, and vice versa. Given there were no significant sex or weight status differences in the current study, the results presented here suggest that there is no need for interventions to be sex or weight status specific.

It is important to note that the cut-points to identify the intensity of MVPA of Roscoe and colleagues (2017; >9.3 g/s) was very different from previous PA cut-points proposed by Phillips, et al., (2013; ≥22 g/s). The potential differences in these cut-points could mean that the Roscoe, et al., (2017) cut-points may have overestimated moderate or higher PA, whereas the Phillips, et al., (2013) may underestimate how active the children may be. But, the Phillips, et al., (2013) cut points are devised for older children, whereas the Roscoe, et al., (2017) cut-points are age specific and validated in children from the Coventry and surrounding areas. So, although the PA levels may appear to be high in comparison to other studies, (Janz, et al., 2010; De Bock, et al., 2011; O'Dwyer, et al., 2011; 2013; 2014), this is more likely to be attributed to an active group of children rather than the cut-points overestimating PA.

The strengths of this study include the use of a process-orientated measure of MC (TGMD-2, Ulrich, 2000), and objective and validated measurement of PA in children aged three to five years. Additionally, the TGMD-2 is a commonly used and investigated MC assessment measure present in a large proportion of MC studies (Klingberg, et al., 2018). It focused on three-to-five-year old children, an understudied but possibly significant age group, particularly given the closeness to adiposity rebound in children. Even with a 94% compliance rate, this study is still not without limitations. The cross-sectional design, which means causality cannot be inferred, may have underestimated PA, as accelerometers were removed during water-based activities, which included swimming; however, the accelerometers used have been identified as a valid method to capture PA (Esliger, et al., 2011). Not explicitly measuring stability skills separately could be deemed a limitation, however Ulrich (2000) suggests that in order to perform the skills in the TGMD-2, stability is needed, and so, if stability is poor, then it will be likely that MC scores will be poor.

5.6 Conclusion

This study found positive associations between PA and MC in British preschoolers. These associations are particularly strong with TPA and overall MC and LC, and MVPA with overall MC and OC. This study suggests that good motor competence is an important correlate of children meeting physical activity guidelines for health. The novel finding is MC was significantly different between children that met PA recommendations for health and children that did not. Overall MC was significantly better in children that completed all PA recommendations (TPA, MVPA, and combined). Children were significantly more proficient in LC if they completed ≥180 minutes of TPA per day, and OC was significantly better in children that completed ≥60 minutes of MVPA per day. This finding provides more detailed understanding of the relationship between PA and MC and can be used in the development of impactful interventions to improve MC and PA in this age group. It is possible that different aspects of MC may be required to promote PA and vice versa and may be used to encourage an active lifestyle in young children. However, longitudinal research is needed to better understand causal relationships between MC, PA, and weight status, but the findings from the current study can be used to inform the design of developmentally appropriate interventions targeting PA and MC for effective preventative medicine strategies to be initiated to improve PA and MC, and reduce obesity, in early childhood.

Stodden, et al.,'s (2008) model suggests perceived MC may mediate associations between PA and actual MC, but this may not be apparent in early childhood. This has yet to be empirically determined in British preschoolers. Thus, Study Two shall explore mediating capabilities on the associations between PA and MC.

Thesis Map Study Two

	Aims	Key findings
Study One: Relationships between motor competence, physical activity and obesity in British preschool aged children	• To investigate associations between weight status, physical activity (PA) and motor competence (MC), as proposed by the Stodden, et al., (2008) model. • To identify current PA levels and compliance to PA recommendations.	• Associations were identified between physical activity (PA) and motor competence (MC). • Associations were identified between total PA (TPA) and MC; TPA and object-control motor competence (OC); moderate-to-vigorous PA (MVPA) and MC and MVPA and OC. • When controlling for BMI: MC was significantly higher in children that completed TPA, MVPA and both recommendations. • When controlling for BMI: locomotor motor competence (LC) was significantly higher in children that completed ≥180-minutes of TPA recommendations. • When controlling for BMI: OC was significantly higher in children that completed ≥60-minutes of MVPA recommendations. • No sex- or weight status differences were identified in minutes spent TPA or MVPA; compliance to TPA, MVPA or both recommendations; or MC, LC and OC.

Study Two: Does perception of motor competence mediate associations between motor competence and physical activity in preschool children?	• To examine if associations between PA and actual motor competence in British preschool children are mediated by perceived MC, as suggested in the Stodden, et al., (2008) model.	
Study Three: Moderate-to-vigorous physical activity is more important than motor competence in maintaining healthy weight status in British preschool children.	• To identify the strongest contributor to current BMI, from previous BMI, and previous and current PA and MC. • To identify the strongest contributor to current PA, from previous PA, and previous and current BMI and MC. • To identify the strongest contributor to current MC, from previous MC, and previous and current BMI and PA.	

6 Study Two: Does perception of motor competence mediate associations between motor competence and physical activity in preschool children?

6.1 Abstract

Introduction: Perceptions of competence in movement skills has been shown to mediate associations between physical activity (PA) and motor competence (MC) in older children (Barnett, et al., 2008). **Aims:** to examine if the relationship between PA and actual MC in British preschool children is mediated by their perceived motor competence. **Methodology:** MC was assessed with six locomotor skills (LC) and six object-control skills (OC) via the Test of Gross Motor Development-2. PA was measured via a wrist-worn triaxial accelerometer and PA grouped as daily total PA (TPA) and moderate-to-vigorous PA (MVPA). Perceived MC was assessed using the Pictorial Scale of Perceived Competence and Acceptance for Young Children. A total of 38 children aged between 3-to-6 years (63% male; 5.41 ± 0.69 years) completed all assessments. Mediating impacts of perceived MC on the relationships between PA and MC were explored via backwards mediation regressions. **Results:** There were no mediating impacts of perceived MC on the relationship between PA and actual MC. **Conclusions:** The relationship between actual MC and PA is not mediated by perceived MC in a small sample of British preschool childhood.

6.2 Introduction

In the prior chapter, associations between physical activity (PA) and motor competence (MC) were identified during baseline assessments. So, using the Stodden, et al., (2008) model, this study will explore the mediating role that perceived MC has on associations during follow-up assessment.

As previously discussed in prior chapters in more detail, increased fatness in childhood is associated with obesity and obesity related diseases in adulthood including cardiovascular disease, diabetes, and some cancers and is a public health priority to reduce (WHO, 2010). PA is one proposed solution to reduce overweightness and obesity (Lubans, et al., 2010). Aside from reducing fatness, PA benefits such as reducing the risk of diabetes mellitus, cancer (colon and breast), and mental ill-health are well established (Warburton, et al., 2006). The preschool (≤6 years) age group is an opportune time for intervention as children in this age range are keen participators in PA, and new positive behaviours may be learnt to prevent unhealthy fatness (LeGear, et al., 2012). Overweight children are less physically active than healthy weight children (Stodden, et al., 2008; O'Dwyer, et al., 2011) and there is overall concern that children are not participating in enough PA for health benefits (Hallal, et al., 2012). In order to promote effective PA engagement for health benefits, it is important to understand correlates and mediators of PA (Lubans, et al., 2010; Babic, et al., 2014).

Stodden, et al.,'s (2008) conceptual model (Figure 2.1, Page 38) proposes that MC is a precursor to PA and learning to move is necessary for PA participation and subsequent healthy weight. Actual MC, composed of locomotor MC (LC) and object-control MC (OC), is positively associated with PA engagement (Lubans, et al., 2010). Children's participation in PA influences MC and in return MC influences PA (Stodden, et al., 2008). Individuals develop MC in childhood to form the foundation for lifelong PA (Clark, et al., 2002) and specifically learning to move effectively within space forms LC (running, galloping, skipping, hopping, sliding and leaping) and learning to manipulate objects forms OC (throwing, catching, bouncing, kicking, striking, and rolling; Haywood and Getchell, 2009). Perceived MC is a proposed mediator of the relationship between actual MC and PA in early childhood (Sallis, et al., 2000; Biddle, et al., 2005; Stodden, et al., 2008).

However, there is a concern that children with lower perceived MC may lose motivations to participate in movement related tasks and reduce PA engagement (Robinson, 2011). However, whilst associations between PA and actual MC have been explored in young children (Foweather, et al., 2015), few have investigated the mediating role that perceived MC plays on PA and actual MC.

In children, perceived MC has been shown to be misaligned to actual MC, but as age increases, this misalignment declines (Noordstar, et al., 2016; Washburn and Kolen, 2018). Inaccuracies in perceived MC may be due to limited cognitive abilities that develop as children age (Noordstar, et al., 2016). Increased perceived MC is positively associated with PA (Carroll and Loumidis, 2001; Barnett, et al., 2008; Khodaverdi, et al., 2016) and children's perceived MC should be considered when attempting to increase PA (Khodaverdi, et al., 2016). Whilst, perceived MC has been shown to have correlations with PA (Carroll and Loumidis, 2001; Biddle, et al., 2005; Barnett, et al., 2008; Babic, et al., 2014; Khodaverdi, et al., 2016) and with actual MC (Lubans, et al., 2010; LeGear, et al., 2012; Noordstar, et al., 2016; Lopes, et al., 2018), there is a paucity of studies investigating how self-perceptions of MC, LC and OC, mediate associations between PA and MC, as suggested by Stodden and colleagues (2008).

When reviewing the mediating capacity of perceived MC, one study tracked children from middle childhood (average age 10.1 years) over 6 years in Australian adolescents (Barnett, et al., 2008), to find that childhood MC and adolescent self-reported PA was mediated by perceived sports competence, suggesting the role of perceived sports competence longitudinally on future PA. Additionally, in older Irish children, aged 12.26 ± 0.037 years, perceived athletic competence mediated the role between PA and MC (Britton, et al., 2019). If children believed their athletic performance was better, then the reciprocal relationship between MC and PA was stronger. In a differing study (Khodaverdi, et al., 2016) in Iranian females in middle childhood (8-to-9 years) found perceived MC mediated the relationship between MC and self-reported PA, again suggesting the mediating capabilities of perceived MC on PA. As did a further study (Chan, et al., 2018), in 7-to-11-year olds in Hong Kong, that found perceived MC mediated the relationship between LC and self-reported PA, but not with objectively measured PA. Thus, the mediating role of perceived MC could provide a potential intervention technique, as if children maintain higher levels of perceived MC, then PA and MC will improve, which would have positive health and weight status benefits.

Nevertheless, one important study in Canadian preschoolers (Crane, et al., 2015) investigating perceived MC, actual OC and moderate-to-vigorous PA, perceived MC did not mediate associations between actual OC and MVPA, imperially confirming Stodden, et al.,'s (2008) conceptual model in this cohort. Whilst this study provided an insight into the mediating effects of perceived MC in preschoolers, it only included actual OC, and did not include LC or overall MC, nor total PA (TPA). It would be of use for a study to explore the mediating role of perceived MC in this age group when considering overall MC, LC and OC as independent categories, in addition to MVPA and TPA.

Whilst the previously discussed literature provides some insight into the mediating potential of perceived MC on the relationships between PA and MC, as no study to date as explored mediating effects in British preschool children. Therefore, the aim of this study was to explore associations and mediating occurrences between PA, perceived and actual MC; and to evaluate perceived MC mediating effects between PA and actual MC in early aged British children (aged 3-to-6 years). The novelty of this study is to assess PA, actual and perceived MC in valid methods whilst separating components of PA and MC in a yet under researched population. This study recognized that PA may be differentially associated with MC, so PA was explored as total PA (light, moderate and vigorous PA) and moderate-to-vigorous PA (MVPA) separately according to current PA recommendations (WHO, 2010). Additionally, this study recognized that LC and OC skills may be different associated within the theoretical model, therefore MC was explored as total MC (all skills), LC skills and OC skills separately. This study used validated and objectively measured PA with cut-points validated in British preschoolers (Roscoe, et al., 2017). Additionally, an objective measure of actual MC was used (Ulrich, 2000) alongside a complimentary measurement of perceived MC (Barnett, et al., 2015).

6.3 Methods

6.3.1 Participants

Following institutional ethics and parental approval, (P37708; 14th December 2015; Ethics Committee, Coventry University), an initial sample of 92 healthy preschool participants from Coventry and Warwickshire were recruited, and data collection occurred between January and May 2016. Preschools and schools were recruited using convenience sampling and were all state funded. Schools and preschools that were recruited from varied socioeconomic backgrounds, and all participants attended school or preschool for ≥15 hours per week. A total of 38 children complied with assessment criteria and were included in the final sample, only 41% of participants had complete physical activity (PA) data, 94% had complete actual motor competence (MC) data, and 98% had complete perceived MC data. A final sample consisted of 38 children (4-to-6-years old; 5.37 ± 0.79).

6.3.2 Procedures

6.3.2.1 Anthropometric Measures

Body mass (to the nearest 0.1 kg) and stature (to the nearest 0.1 cm) were measured objectively by trained researchers using digital scales (SECA 875) and portable stadiometer (SECA 217) and gave body mass index (BMI: kg/m^2).

6.3.2.2 Motor Competence

6.3.2.2.1 Actual Motor Competence

Actual MC was assessed using the TGMD-2 (Ulrich, 2000) in school facilities. Six locomotor (run, jump, hop, leap, gallop and slide) and six object-control (catch, throw, kick, bounce, strike and roll) skills were assessed. Each skill comprised three to five components, and skill mastery on the TGMD-2 requires each component to be present. Video recordings of each skill (Sony Handicam CX405b, Sony, UK) were edited recordings into single-film clips of individual skills with Quintic Biomechanics analysis software v21 (Quintic Consultancy Ltd., UK). The protocol for the TGMD-2 was followed in accordance with the guidelines (Ulrich, 2000), as discussed previously (Motor Competence Assessment; Page 71). The skills identified as LC and OC were grouped together according as subtest scores (LC scored 0-to-48; OC scored 0-to-48) and the summing of these gave a total MC (TMC) score (0-to-96). All analyses were completed by two trained researchers. Intra- and inter-reliability was established for MC assessments within 15% of final data set. Intra-rater reliability across LC and OC showed 93.0%, and 81.0% agreement, respectively. Inter-rater reliability showed 90.0%, and 81.0% agreement across LC and OC, respectively.

6.3.2.2.2 Perceived Motor Competence

The pictorial scale of perceived movement skills competence for young children (PSMC; Barnett, et al., 2015) based on the TGMD-2 (Ulrich, 2000) was used to assess perceived MC 24-to-48 hours before MC was assessed. The

PSMC uses a four-point Likert scale response variable (range 1-to-4). The PSMC is a reliable and valid measure of perceived MC in young children (aged 5-to-7 years; Barnett, et al., 2015; Diao, et al., 2018; Tiejens, et al., 2018; Valentini, et al., 2018; Vanetsanou, et al., 2018). The children completed the perceived MC assessment one-on-one with a trained researcher with males and females receiving specific booklets (Barnett, et al., 2015). For each skill, children were shown two, sex-specific illustrations of a child performing the skill competently or incompetently and were then asked, "This child is pretty good at [skill], this child is not so good at [skill]; which child is most like you?" Children when then asked to select a descriptive for further detail; for the competent illustration 4 – really good, 3 – pretty good, 2 – sort of good, or 1 – not so good. Possible scores for perceived MC ranged from 12-to-48.

6.3.2.3 Physical Activity

Physical activity (PA) was assessed over four consecutive days using wrist worn triaxial accelerometery (GENEActiv, ActiveInsights, Cambridge, UK), including two weekend days (Trost, et al., 2005; Janz, et al., 2010) on the child's dominant wrist (Esliger, et al., 2011) as previously discussed (Physical Activity Assessment; Page 74). GENEActiv monitors have been validated for use in this population with acceptable reliability (Esliger, et al., 2011; Phillips, et al., 2013).

Upon completion of the protocol, each participant's accelerometer data was downloaded and stored on a computer. Using the GENEActiv post-processing software, the raw 100 Hz triaxial GENEActiv data were summed into a signal magnitude vector (gravity subtracted) expressed in 60 second epochs. The accelerometer counts were coded into sedentary (SPA <8), light (LPA 8<9.3), moderate-to-vigorous (MVPA ≥9.3) intensities using previously validated specific cut-points for the right wrist for preschool aged children (Roscoe, et al., 2017). PA was then grouped into TPA and MVPA; this process was conducted to link the analysis in the present study to current recommendations for PA in preschool children, to complete ≥180 minutes of TPA per day and/or complete ≥60 minutes of MVPA per day. Current PA guidelines (WHO, 2010; Department of Health, 2018) recommend children under 4 years to complete ≥180 minutes of TPA and children aged 4-to-17 years to complete ≥60 minutes MVPA of per day.

Inclusion criteria was to complete MC assessments, perceived MC assessments and have ≥600 minutes for four consecutive days of PA.

6.3.3 Statistical Analysis

Descriptive statistics were calculated by all, sex groups, and weight status, and were reported as means (± SD) see Table 6.1. Sex-differences between all variables were assessed using independent t-tests. Analysis was conducted using IBM SPSS Statistics Version 21 (IBM Corporation, New York) with statistical significance set at $P < 0.05$.

To examine relationships between actual and perceived MC, LC and OC and PA (TPA and MVPA), non-parametric mediation analyses were conducted (Preacher and Hayes, 2004). Mediation regressions with either MVPA or PA as the outcome were performed with all predictor variables (MC and perceived MC), followed by a series of mediation regressions with either actual or perceived MC as the outcome were then performed with all predictor variables (PA and MC or perceived MC). The significant influence of the mediating mechanisms (perceived MC, MC, and PA) were established where confidence intervals upper and lower bounds did not pass through zero (Preacher and Hayes, 2004). Non-parametric mediation analysis using the Preacher and Hayes, (2004) model enables the assessment of direct and indirect relationships between two variables that may be mediated buy an external variable. Using G*Power for a parametric mediation, with P at 0.05, power at 80% and to detect a large effect a total sample of 31 participants was required.

When presented in figures, each figure is bi-directional, so each PA (TPA or MVPA) or MC (total, LC or OC) variable can be the independent (X) or outcome (Y) variable. Depending on which mediation analysis is being presented, it may be either underlined or not. Solid lines represent the direct associations between two variables and dashed lines represent the mediating effects of perceived MC between those two variables.

6.4 Results

A total of 41% (n = 38) of the original 92 children completed all physical activity (PA), actual and perceived motor competence (MC) assessments and were included in the final analysis. Of the remaining children, 19% were overweight and obese, 52.6% were Caucasian, 26.3% were black and 15.8% were South-East Asian.

The children were considered sufficiently active, with 260 ± 148 minutes of total PA (TPA) and 212 ± 126 minutes of moderate-to-vigorous PA (MVPA). LC and OC scores were also considered to be ‘average’.

Table 6.1: Mean (± SD) of BMI, physical activity and motor competence

	All Children n = 38	**Males n = 24**	**Females n = 14**
Age (years)	5.37 ± 0.79	5.44 ± 0.68	5.36 ± 0.71
BMI (kg/m^2)	16.48 ± 3.06	16.18 ± 2.53	16.28 ± 2. 53
TPA (mins)	260 ± 148	274 ± 152	241 ± 152
MVPA (mins)	212 ± 126	219 ± 128	207 ± 128
TMC (out of 96)	69.88 ± 8.49	61.19 ± 8.56	58.01 ± 8.56
LC (out of 48)	33.32 ± 4.46	33.34 ± 4.89	33.28 ± 4.89
OC (out of 48)	26.57 ± 6.61 [a]	27.85 ± 6.35	24.73 ± 6.35
Perceived MC (12-48)	39.24 ± 4.01 [a]	39.81 ± 3.80	38.42 ± 3.80

Note: BMI, body mass index; TPA, total physical activity; MVPA, moderate-to-vigorous physical activity; TMC, total motor competence; LC, locomotor motor competence; OC, object-control motor competence; perceived MC, perceived motor competence
[a] Sex-differences identified as significant at the 0.05 level (2-tailed).

There were no significant sex-differences in MC *(P* = 0.08), LC *(P* = 0.95), MVPA *(P* = 0.72), and TPA *(P* = 0.50). However, males were significantly more competent in OC skills *(P* = 0.03) than females and viewed themselves with significantly higher perceived MC *(P* = 0.04). Weight status had no significant influence on MC *(P* = 0.26), LC *(P* = 0.20), OC *(P* = 0.56), MVPA *(P* = 0.31), TPA *(P* = 0.30) and perceived MC *(P* = 0.28).

Non-parametric mediation analysis, shown in Figure 6.1, found actual MC not to be a predictor of perceived MC *(P* = 0.84). Perceived MC was not a predictor of MVPA *(P* = 0.55). Actual MC was not a significant predictor of MVPA *(P* = 0.32). When controlling for the mediator perceived MC, actual MC was not a significant predictor of MVPA *(P* = 0.32). When the predictors were reversed, perceived MC was not a significant predictor of actual MC *(P* = 0.77). MVPA was not a significant predictor of perceived MC *(P* = 0.57). MVPA was not a significant

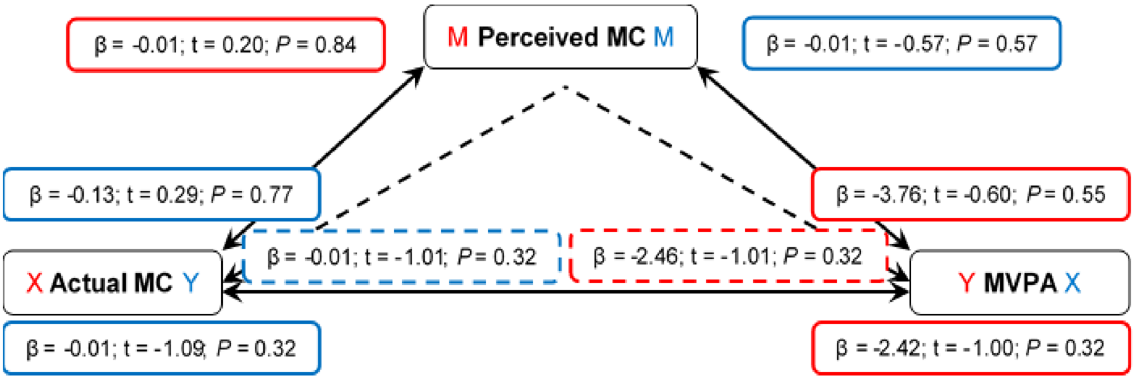

Figure 6.1: *Associations between actual motor competence (MC; Independent X and Outcome Y variable), perceived motor competence (Mediator, M) and moderate-to-vigorous physical activity (MVPA, Outcome Y and Independent X variable). Solid lines represent direct associations between mechanisms and dashed lines represent indirect associations mediated through perceived MC.*

predictor of actual MC (*P* = 0.32), even mediated through perceived MC (*P* = 0.32).

Further analysis, shown in Figure 6.2, found perceived MC was not a predictor of TPA (*P* = 0.29) and neither was actual MC (*P* = 0.48). When mediating the relationship through perceived MC, actual MC was still not a significant predictor of TPA (*P* = 0.46). Therefore, in preschool children, neither MVPA nor TPA is positively associated with increased actual MC as mediated by perceived MC.

In a second series of non-parametric mediation analyses, in Figure 6.3, actual LC was not a predictor of perceived MC (*P* = 0.69). Actual LC was not a

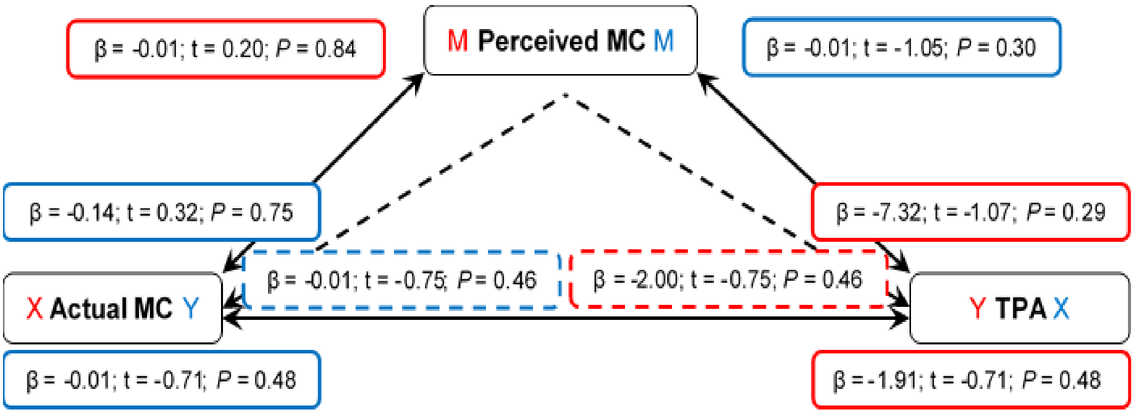

Figure 6.2: *Associations between actual motor competence (MC; Independent X and Outcome Y variable), perceived motor competence (Mediator, M) and total physical activity (TPA, Outcome Y and Independent X variable). Solid lines represent direct associations between mechanisms and dashed lines represent indirect associations mediated through perceived MC.*

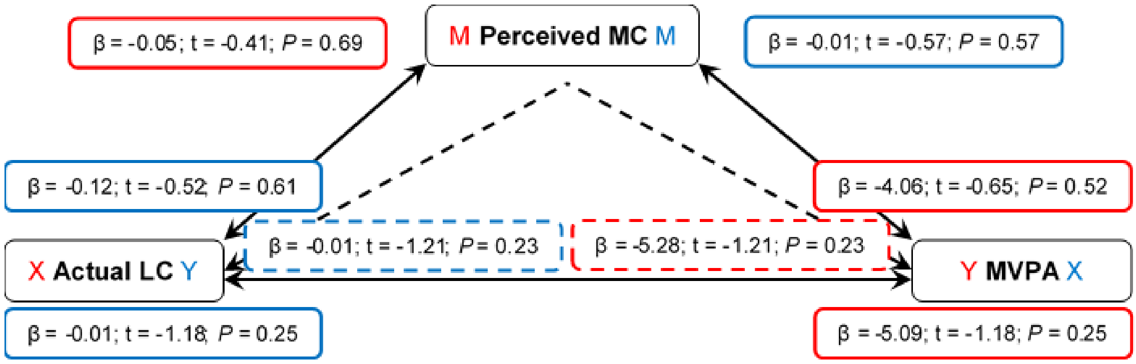

Figure 6.3: *Associations between actual locomotor motor competence (LC; Independent X and Outcome Y variable), perceived motor competence (Mediator, M) and moderate-to-vigorous physical activity (MVPA, Outcome Y and Independent X variable). Solid lines represent direct associations between mechanisms and dashed lines represent indirect associations mediated through perceived MC.*

predictor of MVPA (*P* = 0.25), even mediated through perceived MC (*P* = 0.23). When reversed, perceived MC was not a predictor of actual LC (*P* = 0.61). MVPA was not a predictor of actual LC (*P* = 0.25) even mediated through perceived MC (*P* = 0.23).

Actual LC was not a predictor of TPA (*P* = 0.56) even when mediated through perceived MC (*P* = 0.51) as seen in Figure 6.4. When reversed, TPA was not a predictor of actual LC (*P* = 0.56) even mediated through perceived MC (*P* = 0.51). Therefore, in preschool children, neither MVPA nor TPA is positively associated with increased actual LC as mediated by perceived MC.

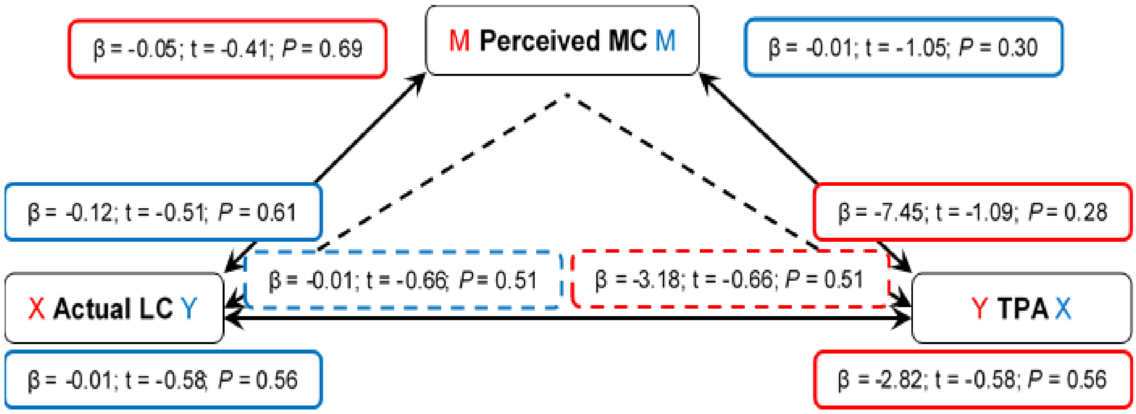

Figure 6.4*: Associations between actual locomotor motor-competence (LC; Independent X and Outcome Y variable), perceived motor competence (Mediator, M) and total physical activity (TPA, Outcome Y and Independent X variable). Solid lines represent direct associations between mechanisms and dashed lines represent indirect associations mediated through perceived MC.*

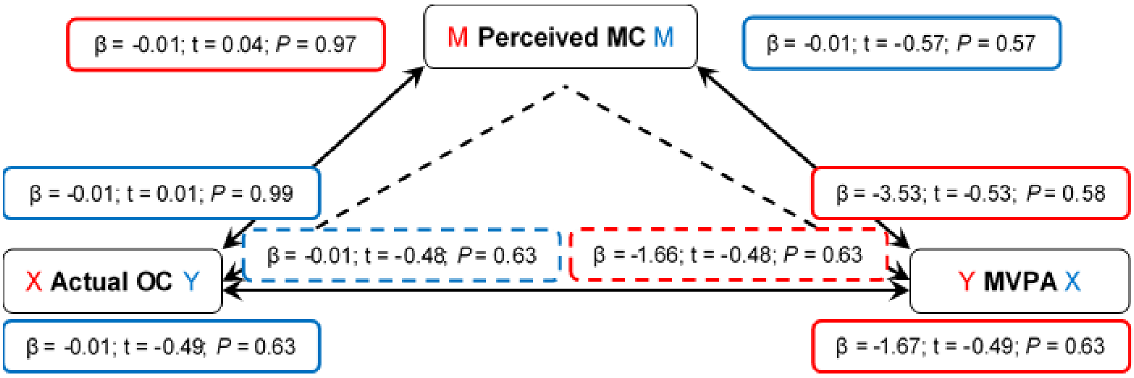

Figure 6.5: *Associations between actual object-control motor competence (OC; Independent X and Outcome Y variable), perceived motor competence (Mediator, M) and moderate-to-vigorous physical activity (MVPA, Outcome Y and Independent X variable). Solid lines represent direct associations between mechanisms and dashed lines represent indirect associations mediated through perceived MC.*

In a third series of non-parametric mediation analyses, in Figure 6.5, actual OC was not a predictor of perceived MC *(P* = 0.97). Actual OC was not a predictor of MVPA *(P* = 0.58), even mediated through perceived MC *(P* = 0.63). When reversed, perceived MC was not a predictor of actual OC *(P* = 0.99). MVPA was not a predictor of actual OC *(P* = 0.63) even when mediated through perceived MC *(P* = 0.63).

Seen in Figure 6.6, actual OC was not a predictor of TPA *(P* = 0.59) even when mediated through perceived MC *(P* = 0.60). When reversed TPA was not a predictor of actual OC *(P* = 0.59) even mediated through perceived MC *(P* = 0.60). All analyses were repeated with sex splits, to no change in the aforementioned

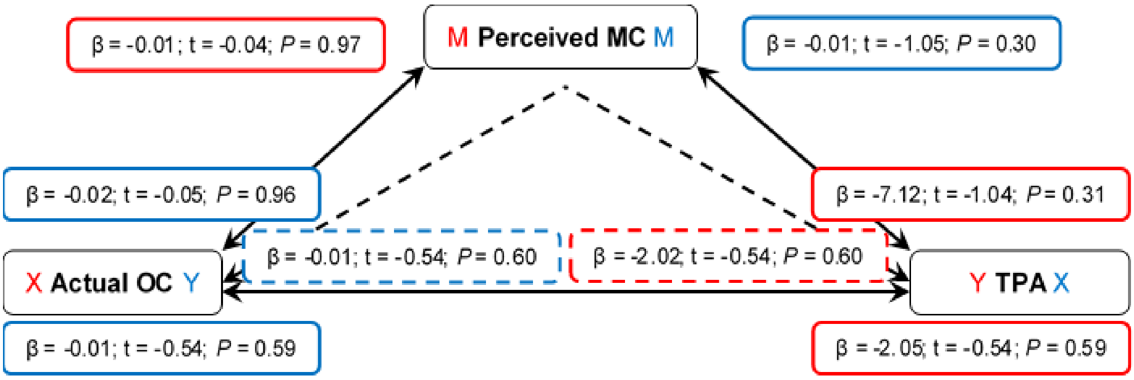

Figure 6.6: *Associations between actual locomotor motor competence (LC; Independent X and Outcome Y variable), perceived motor competence (Mediator, M) and moderate-to-vigorous physical activity (MVPA, Outcome Y and Independent X variable). Solid lines represent direct associations between mechanisms and dashed lines represent indirect associations mediated through perceived MC.*

results. Additionally, all analyses were repeated with perceived LC and perceived OC in place of perceived MC, with no change to the results. Therefore, in preschool children, neither MVPA nor TPA is positively associated with increased actual OC as mediated by perceived MC.

6.5 Discussion

This study examined relations between physical activity (PA), and actual and perceived motor competence (MC) in preschool British children; using objectively measured PA, validated and related measures of actual and perceived MC, no study to date has explored this topic in a British population.

Stodden, et al.,'s (2008) conceptual model suggests that preschool children have limited accuracy of perceived MC, and generally show inflated perceived MC compared to actual MC (Harter, 1999). It is expected that children under 7-years old would have limited cognitive ability to accurately distinguish between actual MC skill ability and effort (Harter, 1999).

This study contributes new data to the area by empirically confirming Stodden, et al.,'s (2008) conceptual model in British preschool children. Stodden, et al.,'s (2008) model suggests that perceived MC mediates associations between MC and PA, however these mediating effects will not appear in early childhood. Perceived MC had no mediating effects on the relationships between PA (TPA or MVPA) and MC (total, LC or OC).

Whilst previous literature has explored the mediating effects of perceived MC in young children (Khodaverdi, et al., 2016; Chan, et al., 2018), the findings are limited by the subjective nature of self-reported PA. Self-reported PA has been shown to be overestimated, when compared with objectively measured PA (Hagstromer, et al., 2010). Furthermore, both of the aforementioned studies were conducted in older children. Older children that have transitioned from early to middle childhood, have developed cognitive capabilities for more accurate perceived MC (Stodden, et al., 2008). Thus, whilst these studies identified mediating capabilities in older populations, it is important to identify if this is the case in younger British populations.

Crane, et al., (2015) used accelerometery, the TGMD-2 and PSMC to assess MVPA, actual OC and perceived MC in Canadian preschoolers, but to find that there were no mediating effects of perceived MC, in agreement with the current study. Whilst Crane, et al.,'s (2015) work explored the mediating effects of perceived MC in preschoolers, the study only investigated MVPA, not TPA additionally; and only used OC as the MC component. This age group finds OC skills more difficult than LC skills, and therefore could have grouped children that are poor at OC skills but good at LC skills with children that are poor at both LC and OC. Therefore, this would not be looking at the whole view. This is particularly important as in this age group, LC skills are developed earlier than OC skills, and it would be unlikely for a child in early childhood to have anything other than low OC scores.

The agreement between this study and Crane and colleagues work, suggests that there is no mediating effects of perceived MC on PA and MC until children have aged. Whilst it is likely that these findings are due to the young children's inability to accurately perceive their MC, it also may be related to the tools assessment not being sensitive enough to identify the small changes in MC as children age and develop. Potentially, there could not sufficient difference in the children's MC comparatively because the variances are so minute.

It can be justified that the mediating role of perceived MC becomes more apparent in older age groups as both this study, and the previous work of Crane, et al., (2015) found no mediating capabilities in early childhood. It could be suggested that this occurs between the ages of 5-to-8-years old, as this age range has yet to be explored, as research has either been investigated in younger age groups (Crane, et al., 2015) or older age groups (Khodaverdi, et al., 2016; Chan, et al., 2018).

But this does not mean the role of perceived MC in preschool children should be disregarded. Barnett, et al., (2008) found that perceived MC mediated the longitudinal associations between middle childhood PA and adolescent MC; additionally, actual and perceived MC are associated (Lubans, et al., 2010; Robinson, 2011; LeGear, et al., 2012; Lopes, et al., 2018). Therefore, inflated perceived MC may be an important component to encourage younger children's MC engagement to influence future PA participation. Preschool children may be more willing to persist in MC skills and PA, as at this age children struggle to differentiate between increased effort with increased performance and will therefore engage in MC activities in which they believe they are skilful (Robinson, et al., 2015), which in turn increases PA engagement and such a link may not be seen via cross sectional study. It may be that current perceived MC leads to future PA and actual MC, as preschool children are increasingly likely to participate in activities, they perceived themselves to be good at (Robinson, et al., 2015). According to Stodden, et al., (2008) the transition from early to middle childhood is an important developmental time when perceived MC grows more influential on actual MC and PA. Therefore, any mediating influence of perceived MC begins in later childhood beyond early years. So, maintaining higher levels of perceived MC to ensure when the mediating effects occur, it is not detrimental to the child's PA and MC.

In accordance with previous literature, there were significant sex-differences in perceived MC between males and females (Masci, et al., 2017; Estevan, et al., 2018; Clark, et al., 2018; McGrane, et al., 2018; Pesce, et al., 2018) as males perceived MC was significantly higher than females. Prior studies have tended to report that males perceive themselves more proficient in MC than females (Masci, et al., 2017; Estevan, et al., 2018; Clark, et al., 2018; McGrane, et al., 2018; Pesce, et al., 2018). This current study is the first to investigate mediating effects of perceived MC between PA and MC in preschool children. If females have low perceived MC, then it is expected that, PA will decline also, (Carroll and Loumidis, 2001; Biddle, et al., 2005; Babic, et al., 2014). Children in the preschool are prior to puberty and therefore have limited biological differences between sexes, consequently, apparent differences between sexes must be from alternative factors, such as cultural and societal differences that may enhance or limit physical self-perceptions. Identifying that females have lower perceived MC than males, despite no significant sex-differences in MC, is important as inability to accurately predict perceived MC may impact on children's PA and should be addressed when aiming to promote PA, highlighting preschool females as potential target groups.

The use of TGMD-2 to assess MC in preschool children is consistent with previous literature. Klingberg et al., (2018) argues that the TGMD-2 is feasible in preschool children. Cools and colleagues (2009) compared MC assessment tools and concluded that the TGMD-2 was age appropriate for this cohort. However, the cultural fit of the TGMD-2 in British children must be considered in this investigation. The TGMD-2 has many positives such as performance assessment and emphasis on OC skills, but Cools, et al., (2009) concludes that some skills may not be appropriate to use cross culturally, such as striking, and the over arm throw are both related to baseball, which is not participated with as widely outside of the USA. Interestingly, in the present study, even when some children were explained techniques to strike, many children held the bat in a cricket stance rather than a baseball strike in accordance with TGMD-2, which impacted strike scores. When comparing between Flemish and American children, (Simons, et al., 2008) Flemish children significantly lower than Americans on the TGMD-2, concluding that cultural differences may explain this underachievement. Therefore, British children, who have limited exposure to baseball skills (strike) or basketball skills (dribble) and overexposure to soccer-based skills (kicking), may limit the exposure to all skills of the TGMD-2. It would be sensible to appreciate that the investigated cohort in this thesis were British, which means the likelihood of being exposed to skills like striking would be limited. This would have an impact on their OC scores, and ultimately their overall MC scores, as if the children do not recognise the skill then they will perform it more poorly than a skill they would recognise.

Some methodological limitations need to be acknowledged. Firstly, the reduction from 92 to 38 participants with full data should be considered. Such a decline is not uncommon when dealing with preschool children and, in the current study, was largely due to children not fully complying with the need to wear accelerometers for the minimum ≥600 minutes per day for four full days. This potentially highlights the practical challenges in collecting objective PA data in young children. However, this does mean that the findings of this study may have limited representability of the British preschool population. Whilst the cohort were from varied socioeconomic backgrounds, this sample may be too small to have generalised results for the preschool age range. This may be due to inflated estimated effect size or have low reproducibility. Any findings from this study may have limited applicability and representation to generalize mediating effects in all British early years children. In the present study, at the time of analysis there was no method of sample size calculation for non-parametric mediation available, hence why the power calculation was based on that for a parametric mediation. This however should be acknowledged as a limitation as more recent literature (Schoermann, et al., 2017) has suggested this approach will systematically underestimate the sample size needed to test the indirect effect and does not generalize to quantities from complex mediation models. Recognizing this we subsequently determined the actual power of our sample using Monte Carlo Methods recently developed by Schoermann, et al., (2017). A posteriori analysis indicated that with our sample of 31 participants actual power was 0.67. Future research examining this issue should therefore be aware of this and future work confirming the assertions made in this study with a larger sample are needed. Secondly, the cross-sectional nature meant data was recorded at one specific period and therefore causation cannot be established. Additionally, the accelerometers were removed for water-based activities and therefore, may have underestimated PA however, the accelerometers used have been identified as a valid method to capture PA (Esliger, et al., 2013; Phillips, et al., 2013).

The current study makes a novel contribution to current literature by confirming assertions made by Stodden, et al.,'s (2008) conceptual model in a small sample of British preschool children. Its strengths are the use of a sensitive process-orientated measure of MC (TGMD-2; Ulrich, 2000) that is an appropriate method in this age group (Klingberg, et al., 2018). Additionally, PA was assessed objectively and using validated PA cut-points for preschoolers (Roscoe, et al., 2017). Furthermore, the Pictorial Scale of perceived Motor Competence for young children (PSMC) was devised and based on the TGMD-2, and when used in conjunction provides uninfluenced comparison for actual and perceived MC. The PSMC has also been validated in preschool children (Barnett, et al., 2015). The consistent use of validated, objective measures in the present study allows for meaningful conclusions to be drawn. Finally, this study focused on 3-to-6-year-olds, which is a significant age group considering its closeness to adiposity rebound in children. Additionally, MC develops in early childhood through PA (Stodden, et al., 2008) so it is important to understand associations in this age range. This sample is relatively small; however, it is reflective of the difficulties in recruiting and completing objective assessments of PA and MC in preschool children. Capturing valid PA data of ≥600 minutes over multiple days is challenging in this population and other researchers should be mindful of potentially high attrition rates when assessing PA in young children (≤6 years old). Given that there was no mediating influence from perceived MC; the focus for preschool education should be to encourage and develop children's actual MC skills, before self-perception impacts children's willingness to participate in movement-based activities. Whilst this study provides a small window in young children, it is important to highlight that future work is required to examine the temporal nature of mediating effects of perceived MC on PA and actual MC in a larger cohort, by cross-sectional study, and through observational studies.

6.6 Conclusion

The aim of this study was to explore associations between PA, perceived and actual MC; and to evaluate perceived MC mediating effects between PA and actual MC in early aged British children (aged 3-to-6 years). This study empirically confirmed assertions of Stodden, et al.,'s (2008) conceptual model, that perceived MC had no mediating effects on actual MC (total, LC or OC) and PA (TPA or MVPA) in British preschool aged children. These findings suggest that, in a small sample of children, the preschool may be an important age range for intervention to encourage PA participation and development of actual MC; as it is before perceived MC has any influence on children's inclination to participate in movement skills. It may be of worth for further investigation to address associations during longitudinal analysis to determine the long-term effects of each variable on current PA levels.

It would be important for longitudinal tracking of children in this age group, and their PA, MC and weight status. Therefore, Study Three shall explore the longitudinal associations between MC, PA and BMI to establish causality, as perceived MC had no mediating capabilities in this age group.

Thesis Map Study Three

	Aims	Findings
Study One: Relationships between motor competence, physical activity and obesity in British preschool aged children	• To investigate associations between weight status, physical activity (PA) and motor competence (MC), as proposed by the Stodden, et al., (2008) model. • To identify current PA levels and compliance to PA recommendations.	• Associations were identified between physical activity (PA) and motor competence (MC). • Associations were identified between total PA (TPA) and MC; TPA and object-control motor competence (OC); moderate-to-vigorous PA (MVPA) and MC and MVPA and OC. • When controlling for BMI: MC was significantly higher in children that completed TPA, MVPA and both recommendations. • When controlling for BMI: locomotor motor competence (LC) was significantly higher in children that completed ≥180-minutes of TPA recommendations. • When controlling for BMI: OC was significantly higher in children that completed ≥60-minutes of MVPA recommendations. • No sex- or weight status differences were identified in minutes spent TPA or MVPA; compliance to TPA, MVPA or both recommendations; or MC, LC and OC.

	Aims	Findings
Study Two: Does perception of motor competence mediate associations between motor competence and physical activity in preschool children?	• To examine if associations between PA and actual motor competence in British preschool children are mediated by perceived MC, as suggested in the Stodden, et al., (2008) model.	• Associations between MC and PA (TPA and MVPA) were not mediated by perceived MC. • Associations between LC and PA (TPA and MVPA) were not mediated by perceived MC. • Associations between OC and PA (TPA and MVPA) were not mediated by perceived MC. • Sex-differences were observed in OC: males were more proficient than females. • Sex-differences were identified in perceived MC: males perceived themselves as more proficient that females.
Study Three: Moderate-to-vigorous physical activity is more important than motor competence in maintaining healthy weight status in British preschool children.	• To identify the strongest contributor to current BMI, from previous BMI, and previous and current PA and MC. • To identify the strongest contributor to current PA, from previous PA, and previous and current BMI and MC. • To identify the strongest contributor to current MC, from previous MC, and previous and current BMI and PA.	

7 Study Three: Moderate-to-vigorous physical activity is more important than motor competence in maintaining healthy weight status in British preschool children

7.1 Abstract

Introduction: Physical activity (PA) and motor competence (MC) are suggested determinants of early childhood weight status (Stodden, et al., 2008). **Aims:** To examine if current BMI, PA and MC in British preschoolers is predicted by previous BMI, PA and MC. **Methodology:** 91 children's data was collected at baseline and one year later at follow-up in children aged 3-to-6 years (59% male; 4.28 ± 0.74 years). Objective measures to assess PA (accelerometers), MC (Test of Gross Motor Development-2) and BMI were used. PA grouped as minutes spent in total PA (TPA) and moderate-to-vigorous PA (MVPA). Normality of variables was identified for PA and MC for baseline and follow-up according to Kolmogrov-Smirmov *(P* > 0.05). Backwards regressions were performed with follow-up BMI, PA and MC as the outcome variables. Follow-up BMI was the outcome variable and baseline BMI, baseline and follow-up PA and MC were assessed as the predicting variables. Follow-up PA was the outcome variable with baseline PA, and baseline and follow-up BMI and MC were assessed as the predicting variables. Follow-up MC was the outcome variable with baseline MC, baseline and follow-up BMI and PA were assessed as the predicting variables. **Results:** Previous BMI and current MVPA were identified as the better predictors of current BMI. 96.4% of variance *(P* = 0.001) in each child's follow-up BMI were explained by baseline BMI *(P* = 0.001) and follow-up MVPA *(P* = 0.003); 49.8% of variance in follow-up TPA *(P* = 0.007) were explained by baseline MVPA *(P* = 0.011), TPA (*P* = 0.012) and BMI *(P* = 0.006); 65.0% of variance in each child's follow-up MVPA *(P* = 0.001) were explained by baseline and follow-up BMI *(P* = 0.003; *P* = 0.002), baseline MVPA *(P* = 0.003), and baseline TPA *(P* = 0.003); 27.5% of variance *(P* = 0.051) of each child's follow-up LC was explained by follow-up BMI *(P* = 0.008), follow-up TPA *(P* = 0.037) and follow-up MVPA *(P* = 0.032). **Conclusions:** MVPA is the most consistent variable to maintaining healthy weight status in British preschool children.

7.2 Introduction

In the preceding chapter, the mediating role of perceived motor competence (MC) on associations between physical activity (PA) and actual MC were explored in British preschoolers. Although there were no mediating effects, this has empirically confirmed assertions made in the Stodden, et al., (2008) model. This study will explored the longitudinal nature of associations between PA, MC and BMI, to predict which of the past or present variables predict current PA, MC and BMI.

As previously highlighted, higher levels of physical activity (PA) are associated with a multitude of health benefits in children (Eriksen, et al., 2013). PA patterns have been consistently tracked as children age (Moore, et al., 1995; Janz, et al., 2005; Basterfield, et al., 2011) and it is commonly reported that overweight children are less physically active than their healthy weight peers (Stodden, et al., 2008; O'Dwyer, et al., 2011; Basterfield, et al., 2011). As children age, PA declines (Sallis, et al., 2000; Lopes, et al., 2011; Jones, et al., 2013; Lopes, et al., 2018a; Santos, et al., 2018), whilst sedentary and lower PA behaviours track from early to middle to late childhood (Jones, et al., 2013). Tracking studies indicate low PA has strong negative associations with increased adiposity in children (Moore, et al., 1995; Janz, et al., 2005), and children with higher BMI at baseline had increased risk for declined follow-up PA (Moore, et al., 1995). In British 7-to-9-year olds, Basterfield, et al., (2012) found longitudinal declines in moderate-to-vigorous PA (MVPA) was associated with increases in fat mass and BMI in males. But the PA and BMI is a dynamic, reciprocal relationship where there is either a positive or negative spiral of engagement (Stodden, et al., 2008). It is suggested as PA increases BMI will decrease, which will in turn increase PA, but as BMI increases, PA will decrease, which further increases BMI (Stodden, et al., 2008).

Early childhood is a critical time to promote healthy lifestyle behaviours (Jones, et al., 2013) especially given its proximity to adiposity rebound that occurs between 3-to-7-years, where body fatness normally declines to a minimum. PA behaviours established during early childhood track into middle to late childhood, (Hands, 2008; Lopes, et al., 2011; Basterfield, et al., 2011; Jones, et al., 2013; Bryant, et al., 2014; Crane, et al., 2017).

Motor competence (MC) has been shown to increase participation in sports and exercise as a precursor and resultant of PA engagement (Barnett, et al., 2008; Stodden, et al., 2008; Barnett, et al., 2009; Lopes, et al., 2011; Bryant, et al., 2014; Robinson, et al., 2015; Lopes, et al., 2018; McIntyre, et al., 2018) and is also a correlate of weight status (Okely, et al., 2004; Lubans, et al., 2010; Hardy, et al., 2012; Lima, et al., 2018) and age (Lopes, et al., 2011; Crane, et al., 2017). Children that have poor MC when young are unlikely to catch up with their more competent peers as they age, without intervention (Hands, 2008). Baseline MC has also been shown to predict future PA in international preschool populations or British older children, (Barnett, et al., 2008; Barnett et al., 2009; Lopes, et al., 2011; Bryant et al., 2014; Lopes, et al., 2018; McIntyre, et al., 2018) but not in British preschool children. One study, in 6-to-10-year-old Portuguese children grouped as low and middle MC, PA declined overtime, but those with high MC had no PA change in PA (Lopes, et al., 2011). So, it is vital that these skills are learnt for children to fully engage with opportunities for PA. Yet, there is no study to date that has investigated the role MC has longitudinally regarding weight status and PA in British preschool populations.

Consequently, both PA and MC are important for healthy weight in children and positive trajectories of PA and MC contribute to healthy weight, but there is debate regarding importance of correlates of healthy weight in early childhood (Hands, 2008; Barnett, et al., 2009; Lopes, et al., 2011; Barnett, et al., 2015; Noordstar et al., 2016; Crane, et al., 2017; McIntyre, et al., 2018). Several international studies have explored longitudinal associations between PA, MC and weight status in children (Barnett, et al., 2008; Barnett, et al., 2009; Lopes, et al., 2011; Barnett, et al., 2015b; Noordstar, et al., 2016; Crane, et al., 2017; McIntyre, et al., 2018) and in young (6-to-11-years-old) British children (Bryant, et al., 2014). In an Australian study, Barnett, et al., (2008) identified associations between combined-sex OC in childhood and minutes in PA per week in adolescents (P = 0.01), and male OC in childhood and PA in adolescence (P = 0.05). Furthermore, childhood OC at age 10.1-years accounted for 12.7% of the variation in adolescence MVPA at age 16.4-years (Barnett, et al., 2009).

In the Stodden model (2008), PA contributes to MC in early childhood and in middle to late childhood, MC contributes to PA. Also, overweight children have lower proficiency in MC, particularly LC and are less likely to be physically active. Overweight children will experience less success when they attempt to engage in physical skills and PA. However, despite Stodden and colleagues' suggestions, these assertions are hypothetical and yet to be assessed in British preschool children. One British longitudinal study, Bryant, et al., (2014) identified that previous MC was a predictor of future pedometer measured PA, and current MC is a predictor of current BMI in a sample of 6-to-11-year olds. Bryant, et al., (2014) observed that improving MC was necessary to increase PA rather than PA manipulating MC. However, this study is not without its limitations. Pedometers provide an ambulatory value of all PA combined. Intensities of PA are not separated to provide insight to intensity, frequency, patterns and compliance to PA. As preschoolers' PA is sporadic and omnidirectional, pedometery will not pick up changes in PA intensity, in accordance with TPA and MVPA recommendations. As a consequence, tracking of the PA and MC relationship may not be fully understood. The use of accelerometery in such circumstances would provide a more comprehensive overview of MC associations with PA, as intensity and frequency can be established. Additionally, this longitudinal study was in and older population of British children, therefore there is a paucity of information regarding British preschool populations currently.

Although studies have tracked the development of PA, MC and weight status in early children internationally, (Sallis, et al., 1999; Hands, 2008; Barnett, et al., 2009; Lopes, et al., 2011; Barnett, et al., 2015; Noordstar et al., 2016; Crane, et al., 2017; McIntyre, et al., 2018) and in British children (Basterfield, et al., 2011; Bryant, et al., 2014), no study to date has explored this longitudinally in British preschool children. The question remains whether previous or current PA and MC better explain weight status, as early intervention may be crucial.

This study recognises that PA and MC can be divided into subcategories. According to the Department of Health (2018), current PA recommendations for children under 5 years to complete ≥180 minutes of TPA and children aged 5-to-17-years to complete ≥60 minutes MVPA of per day; therefore, PA was separated into TPA and MVPA. Similarly, MC subcategories are locomotor MC and object-control MC, so MC was treated collectively and separately. The current chapter aimed to address this gap by identifying associations between PA, MC and BMI in British preschool children (aged 3-to-6 years), to establish whether PA or MC better predicts weight status. However, identifying which baseline variable predicts future variables is important, as to date this has not been identified.

7.3 Methodology

7.3.1 Participants

Following institutional ethics approval (P37708; 14th December 2015; Ethics Committee, Coventry University), a convenience sample of 166 participants were recruited, (males: 54%; 4.28 ± 0.74 years). At follow-up, a year later, 55% completed follow-up assessments, leaving a sample of 91 children (5.41 ± 0.70 years). Children were assessed January to May 2015, at baseline and followed up a year later in 2016 in the same month to reduce seasonal variance.

7.3.2 Procedures

7.3.2.1 Anthropometric Measures

Body mass (to the nearest 0.1 kg) and stature (to the nearest 0.1 cm) were assessed using digital scales (SECA 875) and portable stadiometer (SECA 217). Body mass index (BMI: kg/m^2) was calculated and weight status was classified as either healthy (1), overweight/obese (2 (Cole, et al., 2000).

7.3.2.2 Motor Competence

Actual MC was assessed using the TGMD-2 (Ulrich, 2000) in school facilities. Six locomotor and six object-control skills were assessed. Each skill comprised three to five components, and skill mastery on the TGMD-2 requires each component to be present. Video recordings of each skill (Sony Handicam CX405b, Sony, UK) were edited recordings into single-film clips of individual skills with Quintic Biomechanics analysis software v21 (Quintic Consultancy Ltd., UK). The protocol for the TGMD-2 was followed in accordance with the guidelines (Ulrich, 2000), as discussed in more detail previously (Motor Competence Assessment; Page 71). The skills identified as LC and OC were grouped together according as subtest scores (LC scored 0-to-48; OC scored 0-to-48) and the summing of these gave a total MC (TMC) score (0-to-96). All analyses were completed by two trained researchers. Inter-reliability was established for MC assessments within 15% of final data set. Intra-rater reliability across LC and OC showed 93.0%, and 81.0% agreement, respectively. Inter-rater reliability showed 90.0%, and 81.0% agreement across LC and OC, respectively.

7.3.2.3 Physical Activity

Physical activity (PA) was assessed over four consecutive days using wrist worn triaxial accelerometery (GENEActiv, ActiveInsights, Cambridge, UK), including two weekend days (Trost, et al., 2005; Janz, et al., 2010) on the child's dominant wrist (Esliger, et al., 2011) as previously discussed (Physical Activity Assessment; Page 74). GENEActiv monitors have been validated for use in this population with acceptable reliability (Esliger, et al., 2011; Phillips, et al., 2013). Upon completion of the protocol, each participant's accelerometer data was downloaded and processed into raw 100 Hz triaxial GENEActiv data, which was summed into a signal magnitude vector (gravity subtracted) expressed in 60 second epochs. Accelerometer counts were coded into sedentary (<8), light (8<9.3) and moderate-to-vigorous (≥9.3) intensities using validated cut-points for the right wrist for preschool aged children (Roscoe, et al., 2017). PA was then grouped into TPA and MVPA. Inclusion criteria was to complete MC assessments and have ≥600 minutes of PA per day for both baseline and follow-up.

7.3.3 Statistical Analysis

The statistical package for social sciences (SPSS Inc., Version 20) was used for all analysis, and statistical significance was set at $P = 0.05$ a priori. Normality of variables was established for baseline and follow-up PA and MC *(P* < 0.05). Independent t-tests were used to identify any weight status or sex-differences in each variable at both baseline and follow-up. Paired t-tests identified significant differences in each variable between baseline and follow-up.

Stodden, et al., (2008) reports reciprocal relationships between BMI, PA and MC, but these are yet to be established directionally in British preschoolers. In order to examine the tenants of the Stodden model in regard to directionality of influence a series of backwards linear regressions were conducted to identify which variables were predictors of the other. Backwards linear regressions are useful when conducting confirmatory analysis (Hinton, et al., 2014). Backwards regressions begin by assessing all variables for significant contribution to the outcome variable, and the least significant is removed through each model, until significance has been achieved. If no significance is achieved, then variance in the outcome variable was not explained by the independent variables included (Field, 2009). Baseline and follow-up BMI, PA and MC were evaluated as predictors of outcome variables (follow-up BMI, PA and MC). Backwards regression analyses identify any predictor that does not make a significant ($P > 0.05$) contribution to the predictive power of the model, it is removed, and contribution from remaining predictors is then reassessed.

The first regression performed included follow-up BMI as the outcome variable, with baseline BMI, baseline and follow-up PA, and baseline and follow-up MC as predictor variables. In the second series of regressions, follow-up PA, as either TPA or MVPA, were the outcome variables with baseline PA, baseline and follow-up BMI and baseline and follow-up MC. The third set of regressions, MC was the outcome variable, as total, LC and OC; with baseline MC, baseline and follow-up BMI and baseline and follow-up PA as the predicting variables.

7.4 Results

Demographic data is displayed in Table 7.1. Males began with 16.7% considered overweight at baseline to 18.5% at follow-up; and females started the study with 10.8% considered overweight at baseline to 16.2% at follow-up. 56.0% were Caucasian, 22.0% were South-East Asian and 18.7% were black. Between baseline and follow-up, TPA and MVPA declined in all children, except for overweight children’s TPA which improved. Compliance to complete ≥180-minutes of TPA per day declined between baseline and follow-up, as did compliance to completing ≥60-minutes MVPA per day and compliance to both recommendations. No significant sex-group differences between PA minutes or compliance of PA recommendations (Figure 7.1).

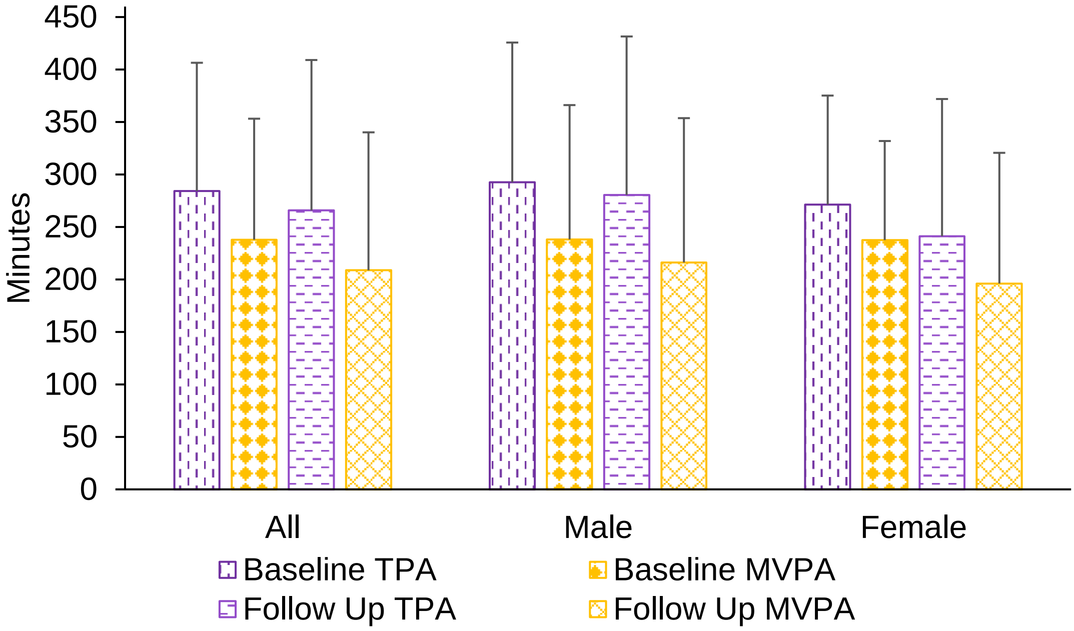

Figure 7.1: *Physical activity in minutes between baseline and follow-up collectively and in sex-groups, as total physical activity (TPA) and moderate-to-vigorous-physical activity (MVPA)*

Between baseline and follow-up, (Figure 7.2) all children's MC, LC and OC skills all significantly improved as participants aged ($P < 0.01$). No significant sex-differences were identified in MC or LC at baseline or follow-up. At follow-up, males were significantly more proficient in OC than females ($P < 0.05$).

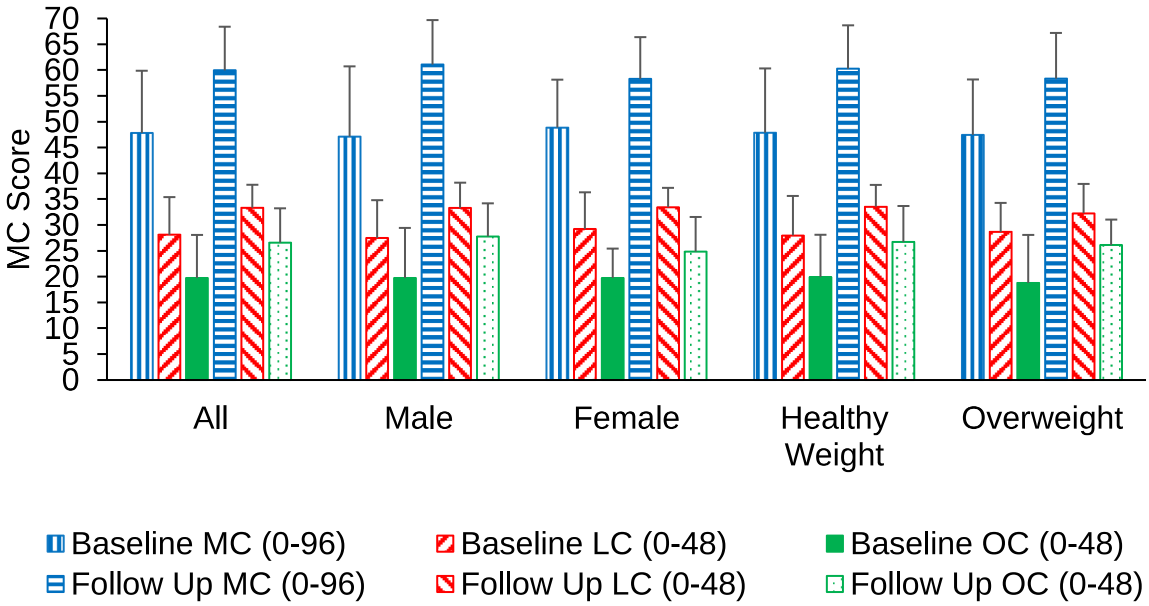

Figure 7.2*: Motor competence between baseline and follow-up collectively and separated into sex-groups, as overall motor competence (MC), locomotor motor competence (LC) and object-control motor competence (OC).*

Table 7.1: Mean (±SD) between baseline and follow-up for BMI, physical activity and motor competence

	All		Male		Female		Healthy Weight		Overweight	
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up
	(n = 91)		(n = 54)		(n = 37)		(n = 78)	(n = 75)	(n = 13)	(n = 16)
Age (years)	4.46 ±0.75	5.41 ±0.70	4.46 ±0.72	5.43 ±0.69	4.46 ±0.80	5.38 ±0.72	4.45 ±0.78	5.38 ±0.72	4.54 ±0.52	5.54 ±0.52
BMI (kg/m2)	16.13 ±1.77	16.22 ±2.39	16.10 ±1.96	16.20 ±2.57	16.18 ±1.49	16.27 ±2.12	15.58 [d] ±1.02	15.60 [d] ±1.49	19.44 [d] ±1.73	19.99 [d] ±3.26
TPA (mins)	284.25 ±122.19	265.74 ±143.32	292.59 ±133.12	280.47 ±170.15	271.32 ±103.89	241.18 ±157.06	285.96 ±116.31	255.62 ±142.94	270.25 ±172.69	313.43 ±146.08
MVPA (mins)	237.92 ±115.25	208.71 ±131.47	238.19 ±127.93	216.23 ±137.46	237.50 ±94.40	196.17 ±124.47	237.40 ±110.43	219.08 ±131.48	242.25 [e] ±158.89	159.82 [e] ±129.54
TPA met (%)	78.4	70.0	77.8	76.0	79.3	60.0	80.3	66.7	62.5	85.7
MVPA met (%)	90.5	85.0	84.4	84.0	100.0	86.7	90.9	87.9	87.5	71.4
Both met (%)	74.3	62.5	71.1	68.0	79.3	53.3	75.8	63.6	62.5	57.1
MC (0-96)	47.81 [f] ±12.06	59.94 [f] ±8.46	47.14 [f] ±13.58	61.08 [f] ±8.61	48.89 [f] ±9.27	58.29 [f] ±8.08	47.89 [f] ±12.43	60.27 [f] ±8.40	47.46 [f] ±10.73	58.33 [f] ±8.86
LC (0-48)	28.11 [f] ±7.26	33.35 [f] ±4.47	27.44 [f] ±7.43	33.29 [f] ±4.92	29.19 [f] ±7.14	33.43 [f] ±3.78	27.98 [f] ±7.63	33.57 [f] ±4.19	28.69 ±5.59	32.27 ±5.68
OC (0-48)	19.70 [f] ±8.38	26.59 [f] ±6.63	19.70 [f] ±9.74	27.79 [a f] ±6.40	19.70 [f] ±5.74	24.86 [a f] ±6.67	4.45 [f] ±8.22	26.70 [f] ±6.94	18.77 [f] ±9.32	26.07 [f] ±4.99

Note. BMI, Body Mass Index; TPA, Total Physical Activity; MVPA, moderate-to-vigorous-physical activity; MC, Motor competence; LC, locomotor motor competence; OC, object-control motor competence

[a] Sex-differences identified as significant at the 0.05 level (2-tailed).
[b] Sex-differences identified as significant at the 0.01 level (2-tailed).
[c] Weight status differences identified as significant at the 0.05 level (2-tailed).
[d] Weight status differences identified as significant at the 0.01 level (2-tailed).
[e] Differences identified as significant between baseline results and follow up results at the 0.05 level (2-tailed).
[f] Differences identified as significant between baseline results and follow up results at the 0.01 level (2-tailed).

7.4.1 Regressions

7.4.1.1 BMI as the Outcome Variable

The first of a series of backwards linear regressions had follow-up BMI as the primary outcome. Follow-up BMI was significantly explained by baseline BMI and follow-up MVPA *(P* = 0.001; Adjusted R^2 = 0.964). Previous BMI (t(16) = 21.211; β = 0.956; *P* = 0.001) and current MVPA levels (t(16) = -3.509; β = 0.158; *P* = 0.003) explained 96.4% (Adjusted R^2 = 0.964) of variance in current BMI. Greater MVPA was associated with lower BMI at follow-up.

7.4.1.2 Physical Activity as the Outcome Variable

The second series of backwards linear regressions had follow-up PA (TPA or MVPA) as the primary outcomes. Follow-up TPA, as the primary outcome, was significantly explained (*P* = 0.007; Adjusted R^2 = 0.498) by baseline BMI, TPA and MVPA. 49.8% of variance in current TPA was explained by previous BMI (t(14) = 0.590; β = 3.214; *P* = 0.006), previous TPA (t(14) = 5.000; β = 2.837; *P* = 0.012) and previous MVPA (t(14) = -5.134; β = -2.910; *P* = 0.011). More previous PA was associated with increased TPA at follow-up.

With follow-up MVPA as the primary outcome, variance was significantly explained (*P* = 0.001, Adjusted R^2 = 0.650) by baseline BMI, TPA and MVPA, and follow-up BMI. 65.0% of variance in current MVPA was explained by previous BMI (t(14) = 2.148; β = 3.613; *P* = 0.003), previous TPA (t(14) = 5.143; β = 3.674; *P* = 0.003), previous MVPA (t(14) = -4.951; β = -3.540; *P* = 0.003), and current BMI (t(14) = -2.213; β = -3.687; *P* = 0.002). Higher PA and lower BMI at baseline were associated with higher MVPA at follow-up.

7.4.1.3 Motor Competence as the Outcome Variable

The final series of backwards linear regressions had MC (total, LC or OC) as the primary outcomes. Neither follow-up MC nor follow-up OC was significantly explained by any predictors *(P* = 0.125; 0.205).

However, follow-up LC as the primary outcome, was significantly explained *(P* = 0.051; Adjusted R^2 = 0.275) by follow-up BMI, follow-up TPA and follow-up

MVPA. 27.5% of individuals' current LC variance was explained by current BMI (t(15) = -0.810; β = -3.039; P = 0.008), current TPA (t(15) = -0.692; β = 2.285; P = 0.037) and current MVPA (t(15) = -0.683; β = -2.367; P = 0.032). Higher current PA is associated with greater current LC proficiency.

7.5 Discussion

This study in British preschoolers is the first to examine predicting variables of BMI, from previous and current PA and MC, and previous BMI longitudinally. There is a scarcity of studies that have examined these associations in preschool populations with objective measures of PA and MC. One study found that previous OC was not a predictor of future sports participation in Brazilian preschoolers (Henrique, et al., 2015). Previous sports participation and LC were predictors of future sports participation, but weight status was not significant predictor of sports participation. Sports participation was measured by parent-reported questionnaire which have been shown to overestimate their children's PA participation (Hesketh, et al., 2013; Lau, et al., 2013). Therefore, the current study, provides original contribution, as PA and MC were measured objectively between baseline and follow-up, as few studies exist examining these associations longitudinally in such young ages.

Baseline BMI and follow-up MVPA explained 96.4% of variance in follow-up BMI. Such a high percentage variance is of interest as it suggests past BMI will explain some of follow-up BMI and follow-up MVPA also explains some of follow-up BMI. Previous BMI contributing to current BMI is unsurprising as both are based around the same variable at different time points. However, current MVPA contributing to current BMI is noteworthy. This finding suggests that it is MVPA, not TPA that contributes to healthy weight status, contradicting previous literature (Basterfield, et al., 2011; Santos, et al., 2018). Current preschool aged PA recommendations suggest that quantity of PA is more important than intensity of PA (Department of Health, 2018). However, this current study suggests that it is the intensity of PA that is more important, MVPA, than TPA when considering future implications on BMI.

Previously, it has been suggested that in British young children, aged 7-to-9-years, TPA was not a significant contributor to weight status, but MVPA was (Basterfield, et al., 2011), and in males, MVPA was a significant contributor of fat mass reductions *(P* = 0.001). However, the present study reports that it was current MVPA that was a contributor to BMI, not previous MVPA, as suggested by Basterfield, et al., (2011). However, Basterfield and colleagues (2001) work did not investigate TPA as time, but averaged the time as counts per minutes, so it is not accumulative TPA but averaged, which could be misrepresentative as to how much TPA children engage with. Furthermore, this study was in older children, aged 7-years at baseline, so is investigating an older cohort than this current study. It would be of interest to establish whether this applies to PA recommendations too. The preschool age range (3-to-6-years) could use either the TPA (≤4-year olds) or MVPA (≥4-year olds) recommendations when assessed collectively, so the suggestion that MVPA recommendations could be more beneficial to maintaining BMI may be of future interest. Additionally, understanding whether moderate or vigorous PA is the more important intensity may also be an area of future research. However, with the current cut points (Roscoe, et al., 2017), this would not be possible, as PA intensity cut points did not separate moderate and vigorous. However, PA above moderate intensity is health enhancing and therefore, these cut-points are sufficient (Roscoe, et al., 2017). The remaining 3.6% of variance unaccounted for is likely due to external variables, such as biological or social differences, such as parental influences, ethnicity and socioeconomic status (Eyre, et al., 2013). So, it is vital that children in this age group obtain habitually consistent MVPA for future BMI maintenance.

Variance of 49.8% in current TPA was explained by only previous variables, including BMI, TPA and MVPA, therefore being physically active with lower BMI previously was associated with higher future PA. This agrees with several prior studies have previously reported that PA engagement demonstrates moderate to low tracking over time (Hands, 2008; Gabel, et al., 2011; Lopes, et al., 2011; Basterfield, et al., 2011; Edwards, et al., 2013; Jones, et al., 2013; Bryant, et al., 2014; Crane, et al., 2017).

This study demonstrates current and previous BMI, and previous TPA and MVPA contribute 65.0% variance in current MVPA. In the conceptual model (Stodden, et al., 2008), a spiral of disengagement is suggested where lower PA will lead to unhealthy weight and obesity, which will in turn feedback into the model to decline PA further. This study has ascertained that previous BMI contributes to current TPA and MVPA. Increased adiposity has been previously linked to declines in PA (Basterfield, et al., 2011). It is clear that BMI and MVPA demonstrate reciprocal relationships by contributing to each other at follow-up.

As children age, PA has been shown to decline (Sallis, et al., 1999; Lopes, et al., 2011; Jones, et al., 2013), it is important to identify that baseline MVPA contributes to follow-up MVPA, and the declining habitual MVPA observed in this study will continue. Therefore, regardless of intensity this decline is apparent in preschool children, but children with lower BMI engage with more PA, physical fitness and sports (Matarma, et al., 2017) which is important for health benefits (Warburton, et al., 2006). It is interesting to note this study found, that baseline and follow-up BMI contributes to follow-up MVPA; and follow-up MVPA contributes to follow-up BMI. Thus, suggesting the relationship between BMI and MVPA, but not overall PA, is within an engagement spiral, as suggested by Stodden and colleagues (2008) in early childhood. Increasing PA in any capacity (TPA or MVPA) has important health benefits (Warburton, et al., 2006), more than just for healthy weight promotion. Consequently, increasing TPA and MVPA, for health benefits is important in this age group, to prevent future physical inactivity.

Declines in PA could be attributed to a variety of factors. As children age, it is suggested that there is a displacement of MVPA to light PA or to sedentary time, which could be related to increases in sedentary behaviours such as watching television (Mutz, et al., 1993) or playing on electronic equipment such as tablets or computers (Dunton, et al., 2011). Additionally, this could also be due to a change from a free flow environment seen in early years settings to more structured time more extensively used in schools (McKenzie, et al., 2010).

A lack of significant predictors for OC in the current study is not unexpected as OC skills are complex and mastered in later childhood (Stodden, et al., 2008).

OC proficiency develops later and involves more intricate skills. Although children may engage in some OC skills more regularly, like kicking, striking a ball with a bat is a skill that is more complicated, and requires more motor coordination to master (Lubans, et al., 2010) which would cause OC scores to remain low. Additionally, it is unlikely that this age group would require OC skills to be active, (Lubans, et al., 2010) as the majority of PA is locomotive based (Janssen, 2014). In this age group, MC proficiency is generally low as these children are not expected to be sufficiently proficient until middle childhood.

The final significant regression observed 27.5% of variance in follow-up LC was explained by follow-up variables: BMI, TPA and MVPA. Follow-up TPA and MVPA partially explaining variance in LC may be related to the skills involved. Locomotor skills, involving running, jumping, skipping, hopping, are transportive movement skills. The more children move, the more they ‘practice’ these skills, which then manipulates LC, so it is understandable that follow-up PA would contribute to follow-up LC. Children with increased BMI have been shown to have greater difficulty with LC (Nervik, et al., 2011), maybe because children with increased adiposity find it more difficult to manipulate their bodies to perform more complicated transportive movement skills. The use of the TGMD-2 to assess LC, means that if children are superior at running but unable to perform other LC skills, such as sliding and hopping, overall LC skill proficiency scores will decline. If children only move in a running pattern, other LC skills are not practiced and improved (Lubans, et al., 2010). Additionally, the children in this study, are in early childhood, which is where MC is beginning to develop as children are at the elementary levels of the skills (Stodden, et al., 2008; Lubans, et al., 2010).

Between baseline and follow-up, MVPA decreased in all groups (all, male, female, healthy weight and overweight), but this decrease was only significant in overweight children with a 34% decrease in MVPA. However, it is interesting to note that although not statistically significant, overweight children were the only group to increase in TPA, so perhaps the decrease in MVPA may be related to overweight children participating in lower intensity PA over MVPA. Displacement of PA from MVPA to TPA occurs in older children as children move from more structured PA opportunities to increases in sedentary behaviour and light PA (McKenzie, et al., 2010). Identification of overweight preschool children demonstrating a displacement in early ages suggests that this displacement may occur at younger ages in overweight children, which could highlight when overweight individuals become less active than healthy weight. However, this is purely speculative and would require further investigation to unpack this. Declines in MVPA are expected to occur as previously identified (Sallis, et al., 1999; Basterfield, et al., 2011). Typically, overweight children have been shown to have decreased MVPA compared to healthy weight counterparts (O'Dwyer, et al., 2014). Basterfield, et al., (2012) found that childhood declines in PA are associated with increased adiposity and suggests that this is due to declines in MVPA rather than TPA, which supports the findings in that overweight children with higher adiposity have declines in MVPA overtime.

Males had significantly higher OC skills that females in follow-up only, which is consistent with baseline literature (van Beurden, et al., 2003; Barnett, et al., 2016; Bardid, et al., 2017; Brian, et al., 2018). In early childhood, MC is influenced by biological maturation, such as limb length, but as they transition to middle childhood, MC is influenced more by practice and opportunity (Barnett, et al., 2016). Sex-differences have often been identified in MC, specifically being male has been identified as a strong positive correlate of OC (Barnett, et al., 2016). What may be of import, is that sex-differences in OC did not occur until the second year, suggesting that sex-related differences occur between 4-to-5 years, and it may be beneficial to research which aspect of OC develops and when, as it may identify potential times that weaknesses develop and therefore can be prevented.

Between baseline and follow-up, MC and OC significantly increased in all groups (all, males, females, healthy weight and overweight) and LC increased significantly in all groups, apart from overweight. MC is expected to increase as children age, as children are in more control of their bodies (Lubans, et al., 2010). LC has been shown to begin development within the first two years of life, beginning with sitting, standing and walking (McGraw, 1975), which is why children are more proficient in LC, earlier, than OC skills. Healthy weight individuals possess more advanced LC than overweight children (Okely, et al., 2004; Southall, et al., 2004; Lubans, et al., 2010). This may be because OC skills are more stationary and to locomotive skills involving more movement which may be more difficult for children with increased adiposity, so small but non-significant improvements may be seen overtime. As OC skills are more stationary based, it may be easier for children with increased adiposity to balance and control their movements in OC skills, than when participating in moving LC skills.

Only overweight children demonstrated a significant decline in MVPA and were the only group to not significantly improve in LC. LC variance was partially explained by follow-up MVPA, suggesting that weight status may have some interaction associations between LC and MVPA. However, this does not identify what is the dependent or independent in the relationship. Namely, this study cannot identify whether weight status influence the associations between PA and MC, or if this relationship influences weight status. These connections suggest that the relationship between LC and MVPA is not fully understood in overweight children and requires further investigation. This also may be able to contribute to potential ideas for intervention focus points, with more research. Also, weight status may be beginning to have stronger correlations in PA and MC at the older age, than at the year previously. The Stodden, et al., (2008) model suggests that there is a negative spiral of disengagement if children obtain lower PA, MC and perceived MC, which contributes to unhealthy weight status and obesity. So, it could be suggested that in this age group, overweight children are beginning to show this negative spiral on disengagement.

The strengths of this study include, firstly, the longitudinal nature of the study that used objective assessment methods of PA and MC, at both baseline and follow-up. Additionally, this study included a comprehensive analysis of predictors of each of the variables within the Stodden, et al., (2008) conceptual model, examining PA behaviours, and considering the role of MC supporting PA behaviour. The TGMD-2 (Ulrich, 2000) is validated in preschoolers to assess MC. Accelerometery provides quantitative outputs for PA, furthermore, the Roscoe, et al., (2017) cut-points are validated for British preschoolers. According to the Department of Health (2018), follow-up PA recommendations for children under 4 years to complete ≥180 minutes of TPA and children aged 4-to-17 years to complete ≥60 minutes MVPA of per day; therefore, PA was separated into TPA and MVPA. Similarly, MC subcategories are locomotor MC and object-control MC, so MC was treated collectively and separately.

Some limitations must also be acknowledged. Firstly, children's PA data was removed from the cohort if data was not for four consecutive days for ≥10 hours between the hours of 6 am to 10 pm. This is reflective of issues when investigating PA in children that other researchers may need to consider. This study included weekend days in PA time, as recommended (Trost, et al., 2005; Janz, et al., 2010), to obtain a comprehensive overview of habitual PA habits. Additionally, PA may have been underestimated as accelerometers were instructed to be removed during water-based activities, which included swimming; however, the accelerometers used have been identified as a valid method to capture PA (Esliger, et al., 2011). However, whilst accelerometery data provides insight to PA intensities it does not look at the type or quality of sedentary behaviour and light PA. Not all sedentary behaviour is equal, and some would involve perfecting other motor competence skills, such as writing, or utensil manipulation and it would be of interest to explore when children were sedentary, was it to develop other skills, or to participate in low quality activities such as participating in television viewing/screen time, or "couch potato time". Therefore, it would be of interest to track what the children were doing during sedentary and light activity compared to other PA intensities to identify what activities may be manipulated or changed to increase PA time. Additionally, this longitudinal study only looked at children between baseline and follow-up in preschool children, it would be important to continue to track children from early childhood to middle to late childhood through to adults to identify if there are behaviours from early childhood that influence future behaviours.

7.6 Conclusion

This study has identified that current MVPA is important in current weight status maintenance in British preschool children aged 3-to-6 years old. There is an engagement or disengagement spiral between BMI and MVPA, not TPA, in early childhood, as suggest by Stodden, et al., and (2008). This study is the first to track British children's PA, MC and BMI in the preschool age bracket; and therefore, conclusions and comparisons to other studies must be taken with some reservations. Further investigation into British children's longitudinal PA using objective and validated measurements may provide a more complete overview of current habitual PA over time. Furthermore, this would be of benefit to use a sensitive process-orientated measure of MC such as the TGMD-2, to track long-term MC development alongside PA in British early years. The preschool is an understudied but possibly significant age group, particularly given the closeness to adiposity rebound in children that requires further investigation. These findings suggest that future public health strategies aimed in the preschool age group should concentrate on increasing MVPA, rather than increasing any intensity PA. Stodden, et al., (2008) suggests that increases in MC will come through MVPA participation. This study supports that MVPA in early childhood is paramount because MC will develop in this age group if children participate in MVPA. But most importantly, to have optimal BMI, engaging in MVPA is more important than engaging in overall PA or perfecting MC skills, which indirectly supports the Stodden, et al., (2008) conceptual model.

Thesis Map Findings

	Aims	Findings
Study One: Relationships between motor competence, physical activity and obesity in British preschool aged children	• To investigate associations between weight status, physical activity (PA) and motor competence (MC), as proposed by the Stodden, et al., (2008) model. • To identify current PA levels and compliance to PA recommendations.	• Associations were identified between physical activity (PA) and motor competence (MC). • Associations were identified between total PA (TPA) and MC; TPA and object-control motor competence (OC); moderate-to-vigorous PA (MVPA) and MC and MVPA and OC. • When controlling for BMI: MC was significantly higher in children that completed TPA, MVPA and both recommendations. • When controlling for BMI: locomotor motor competence (LC) was significantly higher in children that completed ≥180-minutes of TPA recommendations. • When controlling for BMI: OC was significantly higher in children that completed ≥60-minutes of MVPA recommendations. • No sex- or weight status differences were identified in minutes spent TPA or MVPA; compliance to TPA, MVPA or both recommendations; or MC, LC and OC.

	Aims	Findings
Study Two: Does perception of motor competence mediate associations between motor competence and physical activity in preschool children?	• To examine if associations between PA and actual motor competence in British preschool children are mediated by perceived MC, as suggested in the Stodden, et al., (2008) model.	• Associations between MC and PA (TPA and MVPA) were not mediated by perceived MC. • Associations between LC and PA (TPA and MVPA) were not mediated by perceived MC. • Associations between OC and PA (TPA and MVPA) were not mediated by perceived MC. • Sex-differences were observed in OC: males were more proficient than females. • Sex-differences were identified in perceived MC: males perceived themselves as more proficient that females.
Study Three: Moderate-to-vigorous physical activity is more important than motor competence in maintaining healthy weight status in British preschool children.	• To identify the strongest contributor to current BMI, from previous BMI, and previous and current PA and MC. • To identify the strongest contributor to current PA, from previous PA, and previous and current BMI and MC. • To identify the strongest contributor to current MC, from previous MC, and previous and current BMI and PA.	• Current BMI was explained by current MVPA and previous BMI (96.4%). • Current TPA was explained by current and previous MVPA, current LC and current BMI (68.3%). • Current MVPA was explained by previous and current BMI, previous and current TPA and previous MVPA (70.0%). • Current LC was explained by current BMI, current TPA and current MVPA (27.5%). • MVPA significantly declined in overweight children. • MC, LC and OC significantly increased between baseline,

	Aims	Findings
		and follow-up, a year later, in all, males, females, and healthy weight and overweight children. Apart from overweight LC which did not. • Sex-differences were only observed in follow-up OC.

8 General Discussion

The objectives of this thesis were to understand multiple components of the Stodden, et al., (2008) model, by empirically investigating associations between physical activity (PA), motor competence (MC) and BMI in British preschool children. The novelty of this thesis is the investigation between associations between PA and MC but also understanding the mediating capacities of perceived MC and investigating changes in PA, MC and BMI over a year. Reporting PA compliance is of benefit, but many studies have previously reported such data (O'Dwyer, et al., 2011; O'Dwyer, et al., 2013; Foweather, et al., 2015; Roscoe, et al., 2017). This thesis attempted to delve further into understanding the mechanics of these associations and explore the role that PA and MC have on BMI, but also the effects BMI may have too. To date, there is limited literature in this, especially in British preschoolers.

Firstly, a cross-sectional study to establish associations between BMI, PA and MC in British preschoolers with age and population specific cut-points was conducted (Study One: Relationships between motor competence, physical activity and obesity in British preschool aged children; page 83). The Stodden, et al., (2008) model suggests that in early childhood PA contributes to the development of MC. If PA was sufficient, MC would increase, but if not, MC would decline or plateau. Secondly, an observational study explored the mediating role of perceived MC between the relationship of PA and MC in British preschoolers (Study Two: Does perception of motor competence mediate associations between motor competence and physical activity in preschool children? Page 92). Stodden, et al., (2008) model suggests that perceived MC contributes of development of MC and engagement in PA in early childhood. Furthermore, that the relationship between PA and MC can be mediated, or changed, when the role of perceived MC is considered. Namely, does the imaginary alter reality? Thirdly, a longitudinal study investigated the contribution that each variable may have on current or future BMI, PA and MC (Study Three: Moderate-to-vigorous physical activity is more important than motor competence in maintaining healthy weight status in British preschool children, Page 111). The Stodden, et al., (2008) model suggests that as children age the relationship between PA and MC strengthens over developmental time. So initially, the model suggests that PA engagement contributes to MC proficiency in early childhood, but in middle to late childhood, this shifts to MC contributing to PA engagement. However, this was yet to be explored in British preschool aged children and until the model has been empirically assessed in British preschoolers, intervention development may be premature.

The Stodden, et al., (2008) model proposes that in early childhood, engaging in PA is associated with increased MC. Study One found that both total PA (TPA) and moderate-to-vigorous PA (MVPA) were associated with both MC and object-control MC (OC). Additionally, when separating the children that completed the ≥180-minutes of TPA or ≥60-minutes of MVPA recommendations, these children were significantly more proficient in MC than children that did not meet the recommendations. Therefore, regarding the assertions made by the Stodden, et al., (2008) model, PA and MC are associated in early childhood in British children. From Study One, it cannot be determined which variable is the dependent or independent. What is clear, is that compliance to the PA recommendations has clear associations with locomotor MC (LC) and OC skills. Ultimately, this could provide a focus for intervention development, as LC was significantly superior to children that completed ≥180-minutes of TPA and OC was higher in children that completed ≥60-minutes of MVPA. In Study Three (Page 111), 49.8% of variance in current TPA was partially explained by current LC and 27.5% variance in current LC was attributed to current TPA and MVPA. Therefore, this thesis suggests that PA and MC are associated.

As suggested by Stodden and colleagues (2008) MC is a precursor to PA. However, between baseline and follow-up PA has declined, and MC has increased in the same children within the same period (Study Three). So, although associations are identified, having proficient MC is not enough to maintain high PA rates, in males, females, healthy weight and overweight children. MC significantly improved between baseline and follow-up, and PA declined, albeit not significantly, it would suggest that the decline in PA would be stronger had children's MC not improved as intensely. This also agrees with previous literature that PA declines over time (Gabel, et al., 2011; Edwards, et al., 2013).

Previous literature in international preschool children have been suggested to have no significant associations between PA and MC (Bouvin, et al., 2013; Lopes, et al., 2016; Iivonen, et al., 2016; Matarma, et al., 2017). Whilst the observational method used by Iivonen, et al., (2016) provides differentiation between PA intensities, the Observational System for Recording Physical Activity in Children Preschool Version (OSRAC-P; Brown, et al., 2006) was developed for descriptive, not quantitative, purposes. Additionally, the OSRAC-P observed PA every 25-seconds for 5-seconds to give two observations per minute which mean the potential for PA data being missed throughout the minute is substantial, and could be providing an unrepresentative output of PA. Similarly, Bouvin, et al., (2013) may also have unrepresentative PA data, as PA was assessed by accelerometery on only one day, whilst the children were in childcare settings, for a minimum of three hours. As previously discussed, to appropriately measure habitual PA, one day is not sufficient as it is below the recommended three days including one weekend day (Hinkley, et al., 2012; Hislop, et al., 2014). Furthermore, Lopes, et al., (2016) used a MC method of assessment that was designed to measure motor impairment and discriminate among typically developing children. The Movement Assessment Battery for Children is not typically used to assess MC but is designed as a comparative measure to differentiate between children. Similarly, the MC assessment tool used by Matarma, et al., (2017) is also appropriate for individuals with mild-to-moderate motor coordination deficits and not for typically developing children, which may then report high MC results in ‘normal’ preschool populations. But what is distinctive about Matarma, et al.,’s (2017) work is that it included fine movement skill assessments, which was not associated with PA.

Previous literature has found no, or limited, significant associations between MC and PA in British preschoolers (Foweather, et al., 2015; Roscoe, et al., 2019). Both of the previously cited studies separated PA into weekday and weekend day PA. Foweather, et al., (2015) identified associations between weekday MVPA and LC; weekend MVPA and MC and OC; and weekend TPA and OC, whereas

Roscoe, et al., (2019) found no associations in weekday or weekend day TPA or MVPA and MC. Roscoe, et al., (2019) assessed children aged between 3-to-4-years, which may explain why no MC and PA associations were identified, as MC was not sufficiently developed. But more likely, was that no child was identified as sufficiently active by the authors, and met ≥180 minutes of TPA per day, thus differences between children's PA may not have been noticeable enough for associations to be identified in this cohort. This thesis included children in the first year of formal education of primary school, where PE lessons are mandatory. Additionally, the separation of weekday and weekend day PA may limit identification of associations with MC, as a composite of children's PA may be associated with MC.

Overall, in Study One, Two and Three, children were identified as sufficiently active. In Study One, 80.3% of children completing ≥180-minutes of TPA, 89.4% completing ≥60-minutes of MVPA, and 75.8% completing both recommendations. Average daily TPA was 279.7 ± 118.33 minutes and MVPA was 238.7 ± 101.87 minutes. Whilst, it is promising to see such high engagement in PA it is also not a shared view in this age group. Firstly, O'Dwyer, et al., (2011) reports that only ≤25% of healthy weight children completed MVPA recommendations on week- or weekend days, and overweight children did not. Additionally, average time spent in TPA was <105-minutes and for MVPA was <42-minutes of overweight and healthy weight children. Similarly, in a separate study, (O'Dwyer, et al., 2014) preschoolers were insufficiently active, as males and females completed <45-minutes of MVPA at week- and weekend days. Additionally, Er, et al., (2018) suggests that PA is low, at 147.04 and 136.89-minutes of TPA and 22.54 and 21.50-minutes of MVPA, in nursery and non-nursery days respectively. However, Collings, et al., (2017) identified that preschoolers achieved on average 51.4-minutes of MVPA, but over the recommended ≥180-minutes of TPA per day of 293.4-minutes of daily TPA. In a separate study, Collings, et al., (2013) found children were sufficiently active with 508.3-minutes of TPA and 84.7-minutes of MVPA per day. Variation in PA from previous literature, may be due to accelerometer placement. All of the aforementioned studies placed the accelerometers on the torso, which can inhibit adequate capture of static activities involving isolated limb movement (O'Dwyer, et al., 2011; Collings, et al., 2013; O'Dwyer, et al., 2014; Collings, et al., 2017; Er, et al., 2018). This thesis used population and age specific cut-points that would provide more consistency to this thesis' PA data. Additionally, by using wrist-worn accelerometers, rather than hip-worn like in previous literature, has been shown to have higher compliance rates in young children (Migueles, et al., 2017).

In addition to minutes of PA, compliance to PA recommendations was associated with MC, LC and OC. Total MC significantly increased if ≥180-minutes of TPA, ≥60-minutes of MVPA and both combined recommendations were completed; LC was significantly better in children that complied with ≥180-minutes of TPA; and OC was significantly better in children that completed ≥60-minutes of MVPA. Therefore, it would be suggested improving MC will improve TPA and MVPA levels, improving LC will improve TPA and improving OC will improve MVPA. It can reasonably be suggested that light PA (LPA) is the differentiating intensity of PA that alters associations with LC and OC. It is unclear as to why TPA is more strongly associated with LC but in Study Three, current LC contributed to some variance in current TPA, and current TPA contributed to some variance in current LC. Thus, it would be of interest to explore associations with MC from all PA intensities separately and combined.

No sex- or weight status differences were identified in PA in any study (One, Two, and Three). Lack of sex-differences in children before puberty is to be expected, as biological maturation is yet to occur which will provide differences between males and females and therefore influence limb length, which consequently could alter PA (Malina, 2004). Whilst several studies support the conclusions that sex has limited influence on PA in preschoolers (Cliff, et al., 2009; Johansson, et al., 2015; Miller, et al., 2018; Morrison, et al., 2018), several others dispute this (O'Dwyer, et al., 2014; Foweather, et al., 2015; Hesketh, et al., 2015; Er, et al., 2018). Any sex-differences identified in such studies, may be attributed to assessment methods, such as no inclusion of weekend day PA (Hesketh, et al., 2015; Er, et al., 2018), assessment of PA in preschool settings only (Er, et al., 2018), assessing PA with uniaxial accelerometers (O'Dwyer, et al., 2014; Foweather, et al., 2015; Er, et al., 2018), assessing PA with heart activity monitors which had counts converted into PA counts (Hesketh, et al., 2015), or not using age appropriate PA cut-points (Er, et al., 2018). This makes for comparison between studies difficult as there is no standardised assessment technique. However, this thesis used triaxial accelerometers, which have advantages over uniaxial, which as been suggested to not be sufficiently sensitive to quantify PA levels in young cohorts (Hislop, et al., 2013) and recorded PA data over several consecutive days including two weekend days, as recommended (Hinkley, et al., 2012), with age and population specific PA cut-points (Esliger, et al., 2011; Phillips, et al., 2013; Roscoe, et al., 2017). The aforementioned studies (Cliff, et al., 2009; O'Dwyer, et al., 2014; Foweather, et al., 2015; Johansson, et al., 2015; Er, et al., 2018; Miller, et al., 2018; Morrison, et al., 2018) failed to comply with all the stringent PA regulation used in this thesis.

Sex-differences in MC, LC and OC were not observed, until follow-up assessments, were males had significantly higher OC than females (Study Two and Study Three). Being male has previously been identified as a correlate of OC in preschoolers (Barnett, et al., 2016), and in this cohort suggests that sex-differences become apparent at older ages (5.41 ± 0.70 years) compared to younger (4.46 ± 0.75 years). Several studies have identified sex-differences in preschoolers' OC (LeGear, et al., 2012; Foulkes, et al., 2015; Foweather, et al., 2015; Crane, et al., 2017; Roscoe, et al., 2019). It is suggested that there are societal or cultural impacts that cause these sex-variations as biological maturation is unlikely to occur at this age (Rivers and Barnett, 2008; 2013). OC skills involve kicking, bouncing, throwing all skills seen in male dominated sports. One potential reason for sex-differences is males are more likely to be encouraged to participate in games such as football, basketball and rugby; and traditional female games involve sitting playing 'dollies' or participating in expressive arts and design (O'Connor, et al., 2014). Sex-differences in children's play activities may be the cause of variation between sex-groups' MC skills at a younger age.

In this thesis, MC improved significantly, including LC and OC, in the majority preschoolers, except for LC in overweight children. In previous literature, MC has limited associations with BMI in preschool aged children (Roscoe, et al., 2019). In early childhood, MC is in the initial stages of development and would therefore have limited implications on weight status and PA. No weight status differences were identified in MC, including LC and OC. However, in Study Three between baseline and follow-up, overweight children's LC did not significantly increase like in other categories (male, female and healthy weight). This would suggest, that either weight status is not sufficiently impactful to alter MC, or more likely that MC was not established sufficiently in this young age group for sensitive weight status differences to be identified.

Stodden, et al.,'s (2008) model (Figure 2.1) suggests that associations between PA and MC appears in early childhood and as children age this relationship becomes stronger. This relationship is suggested to be mediated by perception of MC, and in particular, perceived MC is predicted to influence both PA and actual MC in early childhood. As children age, perceived MC is suggested to have a bi-directional relationship with both PA and actual MC. However, this thesis explored mediating effects of perceived MC on associations with PA and actual MC. To date, there are few studies exploring the mediating effects of perceived MC on this relationship in preschool aged children worldwide (Crane, et al., 2015). However, Crane, et al.,'s (2015) work only investigated MVPA, not TPA additionally; and only used OC as the MC component. This age group finds OC skills more difficult than LC skills, and therefore could have grouped children that are poor at OC skills but good at LC skills with children that are poor at both LC and OC. Therefore, this would not be looking at the whole view. This is particularly important as in this age group, LC skills are developed earlier than OC skills, and it would be unlikely for a child in early childhood to have anything other than low OC scores. The agreement between this study and Crane and colleagues work, suggests that there is no mediating effects of perceived MC on PA and MC until children have aged. Whilst it is likely that these findings are due to the young children's inability to accurately perceive their MC, it also may be related to the tools assessment not being sensitive enough to identify the small changes in MC as children age and develop. Potentially, there could not sufficient difference in the children's MC comparatively because the variances are so minute. It can be justified that the mediating role of perceived MC becomes more apparent in older age groups as both this study, and the previous work of Crane, et al., (2015) found no mediating capabilities in early childhood.

Study Two assessed the role of perceived MC in British preschoolers. Firstly, Study Two empirically confirmed Stodden, et al., (2008) that perceived MC has no mediating effects of the associations between PA and MC in early childhood. However, it was important to identify if perceived MC had such effects, as in older children, perceived MC has mediating effects (Khodaverdi, et al., 2016; Chan, et al., 2018).

One study identified mediating effects of perceived MC between PA and MC in Iranian school aged children (8-to-9-years), but PA was assessed through self-report, as was perceived MC and therefore, perception of MC and PA may have associations, which may not be apparent through objectively measured PA (Khodaverdi, et al., 2016). Additionally, in 7-to-11-year olds from Hong Kong, perceived MC mediated the relationship between self-reported PA and MC, but not with objectively measured PA (Chan, et al., 2018). However, in Canadian preschoolers, there were no mediating effects between actual OC and MVPA (Crane, et al., 2015). Study Two recognised the gap in literature to identify if perceived MC mediated the relationship between MC as separate categories of overall MC, LC and OC; and PA as TPA and MVPA; in British preschoolers.

All associations between PA and actual MC were not mediated through perceived MC. All analyses were completed for actual MC as MC, LC and OC; PA as TPA and MVPA; and perceived MC as perceived MC, perceived LC and perceived OC; for children as a collective and for males and females. There were no significant associations when mediated through perceived MC, in any capacity. It was novel to separate the children into sex-groups for analysis, especially considering that males had significantly higher perceived MC compared to females, despite there being no mediating effects also.

Secondly, perceived MC was significantly higher in males than females. In early childhood, children’s perception of their own MC abilities is often inaccurate (Noordstar, et al., 2016; Washburn and Kolen, 2018) due to limited cognitive development. Nonetheless, perceived MC may be an important factor to improve

PA engagement, which would improve MC proficiency through practice and therefore continue to improve PA levels.

Nevertheless, the role of perceived MC in young children should not be diminished. If perceived MC influences PA and MC in older aged children, then maintaining higher rates of perceived MC may contribute to higher PA engagement and more proficiency in MC. It has been demonstrated in older children with inflated perceived MC compared to actual MC were significantly more active than those with low MC who accurately estimated their performance (De Meester, et al., 2016). Therefore, children with lower perceived MC may lose motivations to participate in movement related tasks, which would reduce PA levels (Robinson, 2011). Before self-awareness is more accurate, it would be recommended that inaccurately high, or high perceived MC is encouraged in preschool aged children. Children's perceptions are influenced by the feedback, either supportive or critical, given by parents and teachers, and will therefore be more inclined to participate in activities they believe to be good at (Muenks, et al., 2018).

The number of overweight children increased by 23% between baseline and follow-up assessment (n = 3; Study Three), and all children that were overweight at baseline were overweight at follow-up, thus the overweight group had gained numbers. BMI was identified as significantly different between healthy weight and overweight children in Study Three, which was to be expected. This would highlight that as children age, they are moving from a lower weight status classification to higher. Which is congruent with rising overweight and obesity trends.

In Study Three, 96.4% of variance in current BMI was explained by previous BMI and current MVPA. It is unsurprising that past BMI would influence future BMI. Yearly differences in lifestyle behaviours would not be significantly different, as even with targeted interventions altering behaviours have limited effects (O'Hara, et al., 2016), especially as children's lifestyle behaviours are decided upon by parental controls. What is novel, is the identification that MVPA has a significant contribution to the variance of BMI, which can be modifiable. This contradicts previous literature, which identifies TPA as the contributory factor of healthy weight status (Basterfield, et al., 2011; Santos, et al., 2018). The identified differences could be attributed to the method TPA was identified, as Basterfield and colleagues work (2011) included TPA as mean counts per minute, rather than as time of TPA. This could have limitations to the outcomes, as it is average per minute, rather than overall PA output. Therefore, is not reflective of accumulative TPA which may be more strongly associated with BMI; as total is potentially more important than average counts per minute. Additionally, Santos, et al., (2018) investigated older populations, with the youngest age range of 10-to-14-years old. The older populations could demonstrate TPA contributing to BMI, as the PA displacement has occurred by this point. So, these participants are more likely to engage in TPA, rather than MVPA (Mutz, et al., 1993). In older British children, current MC was the better predictor of weight status (Bryant, et al., 2014). Interestingly, current MVPA was predicted partially by previous and current BMI. It is clear that MVPA and BMI are interlinked in preschoolers and the contributory nature may involve a spiral of engagement, suggested in the Stodden, et al., (2008) model (Figure 2.1). Consequently, it is vital that children engage in MVPA for healthy weight, and those of healthy weight engage in more MVPA.

Additionally, 65.0% of variance in current MVPA was significantly explained by previous and current BMI, previous TPA and MVPA. Previous PA variables contributing to current PA is predictable, as this is already identified in the literature (Sallis, et al., 1999; Lopes, et al., 2011; Jones, et al., 2013), nonetheless, this is of concern as MVPA declines in such young ages between baseline and follow-up predicts further future declines, towards inactive individuals. However, it is important to note that TPA includes MVPA within it, and therefore there is collinearity in the data which may inflate variance of the estimated coefficient.

Similarly, 49.8% variance in current TPA was explained by previous MVPA, TPA and BMI. Previous BMI contributions to PA is a significant identification. Increased adiposity has previously been linked to declined PA (Bürgi, et al., 2011; Basterfield, et al., 2011), and increasing PA may have positive effects on healthy weight status. Healthy weight children may be more active than overweight as they may experience less difficulty in moving around and participating in PA, which then contributes to lower BMI, suggested as the spiral of engagement by Stodden and colleagues (2008).

In overweight children, there was a significant decline in MVPA between baseline and follow-up from 242.25 ± 158.89 minutes to 159.82 ± 129.54 minutes, also overweight children were the only category of children to not significantly improve in LC. As previously discuss, MVPA is a contributing variable to LC. This suggests that overweight children are not sufficiently compliant with MVPA to see significant improvements in LC skills. This significant difference is not seen in any other category of males, females or healthy weight children which may be why it has not yet been identified in previous literature. Stodden, et al., (2008) suggests PA is influential in MC development, and this potentially highlights that in overweight children it is MVPA influencing LC. Additionally, this may also recognise a noteworthy difference between when weight status contributes to lower MC, which ultimately leads to declines in PA in overweight individuals. All relationships were examined as part of Study Three to identify contributory variance to current BMI, PA and MC. This was conducted as the Stodden, et al., (2008) conceptual model suggests there is a change between early and middle childhood of the direction of the contributions of PA and MC, but this was yet to be identified if it was in preschool aged children. Therefore, this study identified all current variables as the outcome variable to ensure that each variable was assessed, as these relationship contributions were yet to be established in British preschool aged children.

The Stodden, et al., (2008) model theorises that in early childhood PA contributes to MC development, and when children transition into middle and late childhood, MC then contributes to PA. Thus far, no study to date has explored this longitudinally in British preschool aged children. But, Study Three advances current understanding of the Stodden, et al., (2008) conceptual model, as it suggests that there is a bi-directional relationship between PA and MC in early childhood, as MC contributes to PA and PA contributes to MC in this age group.

Variance in TPA was partially explained by LC and variance in LC was partially explained by MVPA and TPA.

8.1 Practical Implications

There are several practical implications that can be derived from this thesis. Firstly, compliance to PA recommendations over a year the number of children complying with ≥180-minutes of TPA per day reduced by 8.4%, ≥60-minutes of MVPA per day fell by 5.5% and those that complied with both recommendations was 11.8% lower. Therefore, there is a clear necessity for PA interventions to reduce such declines in children, starting with early childhood before lifestyle behaviours are established (Reilly, et al., 2008), especially considering that MVPA was a significant contributor in BMI.

Secondly, compliance to PA recommendations has associations with MC, as children that complete ≥180-minutes of TPA per day were significantly more proficient in LC and children that were compliant in ≥60-minutes of MVPA per day were higher skilled in OC. Therefore, targeted interventions can be developed regarding development MC and increasing PA engagement. Therefore, if children are less proficient than others in either LC or OC a targeted intervention increasing TPA or MVPA could be devised. Similarly, if compliance to either PA recommendation is low, improvements in either LC or OC could be beneficial.

Thirdly, perceived MC may have a limited role in mediating any associations between PA and actual MC, but its part should not be dismissed. Children are more likely to participate in activities which they perceive themselves good in, and this can be encouraged through adult interaction by encouragement (Muenks, et al., 2018). Therefore, it would be recommended that maintaining overinflated perceived MC is beneficial as it may convince children to engage in more PA and MC based activities in the future. This is particularly important because as children age, accuracy of perceived MC becomes better, so if perceived MC was higher in children initially, the readjustment for more accurate results would hopefully have a more limiting role. Additionally, by the time perceived MC is accurate, in children that have low MC proficiency, there is a greater potential that these children may have found a sport, exercise or physical activity they enjoy and are willing to participate in.

Fourthly, MVPA is the most important variable to contribute to weight status in preschoolers. Current PA recommendations are either completion of ≥180 minutes of any intensity of TPA or ≥60 minutes of MVPA (Department of Health, 2018). Additionally, in the preschool age group, the emphasis is that children should engage it as much PA as possible, that quantity is more important than intensity. However, Study Three suggests that, regarding BMI, MVPA is more important. Therefore, the intensity of PA is more important than the quantity. This suggests that specifically with BMI, moderate or vigorous PA is more important than LPA, but this does not diminish the role of light PA. LC was associated with TPA recommendation compliance in Study One, suggesting that TPA is important for LC development in preschool children. Therefore, it is intensity of PA that is the most important, not completion of TPA, to decrease risk of unhealthy weight status. This finding is contradictory to current UK PA guidelines that suggest it is volume, not intensity, which is important.

8.2 Strengths

This thesis examined the assertions of the Stodden, et al., (2008) model hold true in British preschool, aged children, and is the first to present such information in a British population. A strength is that this study investigated an age group of particular interest considering the closeness to adiposity rebound. Furthermore, whilst Study One and Study Two are cross-sectional, Study Three incorporates longitudinal data to counteract any uncertainty for causality, which to date, there is no other British study that has conducted a similar study in preschoolers, with objective measures of PA and MC. Children were only included in each study if the appropriate inclusion criteria were met, depending on variables.

Additionally, measuring PA through triaxial accelerometery establishes objective PA patterns. Accelerometers were easy and simplistic tools that parents could put on the children. This study assessed PA across two weekend days to establish habitual PA, as suggested previously (Hislop, et al., 2013). The criteria for children to comply with PA criterion is also a limitation, as only data that recorded ≥600-minutes of data per day and ≥4-days of activity were included. Accelerometery is widely considered the best method to assess PA (de Vries, et al., 2009) and is validated in preschool aged children (Esliger, et al., 2011; Phillips, et al., 2011). Moreover, the cut-points used throughout the thesis are validated in preschool aged (Roscoe, et al., 2017). PA was also recognised to have two varying recommendations, depending on age and country. This thesis recognised that compliance to PA may also have significant associations with MC and BMI in preschool aged children, which is usually underreported, as many studies focus on total minutes of PA.

Actual MC was assessed through validated process-orientated measures (Ulrich, 2000). The Test of Gross Motor Development-2 is a widely used tool in children aged between 3-to-10-years, to assess normally developing MC. A large proportion of studies use the TGMD-2 (Klingberg, et al., 2018) when assessing MC as it is a feasible and practical measure. Additionally, MC was investigated as overall MC, LC and OC to assess which components were the most influential. Perceived MC was assessed via the Pictorial Scale of Perceived Motor Competence for Young Children (PSMC, Barnett, et al., 2015) which has been previously validated in preschool aged children. The method uses pictures for the children to identify their own MC performance, and provides questions to ask each child, to prevent questioning bias. Finally, assessment of all variables was completed at baseline and follow-up so that predicting variables could be established.

8.3 Limitations

This thesis is not without limitations. BMI has been shown to be dependent on stage of biological maturation, gender, ethnicity and hip-to-waist-ratio (Adab, et al., 2018), and fails to differentiate between fat mass and fat-free mass, however, it is the standardised measure for weight status that is used across many research studies and by public health professionals and is the government standard measure to classify weight status.

The Roscoe, et al., (2017) cut-points categorise moderate and vigorous PA together, which may provide a more limited view of PA intensities, however, current recommendations in this age group do not differentiate between moderate or vigorous PA. Additionally, children were asked to remove accelerometers during water-based activities, such as swimming and bathing, which means that PA may have been underestimated. This provided several restrictions, as some accelerometers failed to collect enough data, some children refused to wear accelerometers on all days, and some were ‘forgotten’ to be put on for all 4-days. Therefore, these children were excluded. It would be suggested that other researchers consider the challenging aspects of working with such a young age group. This also was found with MC assessments, where some children would not participate in ass MC assessment tasks and were therefore removed from data analysis.

The TGMD-2 is a recognised and validated assessment tool for MC, one limitation is that it does not separately assess stability or balance. The TGMD-2 provides an overview of LC and OC skills, but is based on American children, who are exposed to different skills than British children. For example, the strike is an OC skill that is seen in baseball, but when discussing a strike in Britain, children may copy a cricket stance when attempting to strike. Cultural differences that are seen in the TGMD-2 may therefore impact MC scores. Additionally, the TGMD-2 does provide a comprehensive overview of LC and OC skills, but it does not assess the input of balance and stability skills (Ulrich, 2000). It may be beneficial to assess the role that balance may have on the contribution to LC and OC, but also as part of the associations between PA and MC, especially as the role of stability has been recommended to be included in MC assessment (Rudd, et al., 2015). Additionally, the TGMD-2 has been validated and deemed appropriate in preschoolers, the CMSP as part of CHAMPS protocol must be considered. This has been validated in American preschoolers (Williams, et al., 2009) but for this investigation the CMSP method would have not been comparable to the PSMC that was used to asses perceived MC.

9 Future Research

This thesis aimed to further establish associations in physical activity (PA) and motor competence (MC) with regards to weight status in British preschool aged children. But there is still further investigation to be done. Potential areas for future research include further understanding the impacts that compliance to either ≥180-minutes of total PA (TPA) and ≥60-minutes of moderate-to-vigorous PA (MVPA) to health benefits. Currently, UK recommendations are to complete either of these, but it would be beneficial to identify which of these is more appropriate, and in which age range, as this thesis suggests that MVPA is more important regarding weight status.

Additionally, understanding the implications that intensity of PA has. The exploration of the role sedentary behaviour, light PA, moderate PA and vigorous PA as separate entities has may provide more sophisticated understand of PA influence. This, in turn, may provide further understanding of the associations moderate or vigorous PA has with MC, as total, locomotor MC (LC) or object-control MC (OC) and BMI. Furthermore, accelerometery data provides insights into quantitative data of PA intensities, it does not look at the quality or type of sedentary behaviour or PA. Not all sedentary behaviour is equal, and may provide different MC skills, like writing. It would therefore be important to establish, when children are sedentary, if they are exploring and learning new skills, or engaging in low quality activities such as “coach potato time”. Therefore, it would be of interest to track what the children were doing during sedentary and light activity compared to other PA intensities to identify what activities may be manipulated or changed to increase PA time.

Early adiposity rebound, before age 5-years, is predictive of adult obesity (Ip, et al., 2017), and weight at age 5-years is a good predictor for further health of the individual (Gardner, et al., 2009), therefore suggesting that early childhood is important in obesity prevention.

Perceived MC holds no mediating effects in yearly recorded PA and MC, but it would be important to understand perceived MC effects on PA and MC associations throughout childhood, to fully examine the temporal nature of mediating effects of perceived MC on PA and actual MC in a larger cohort, by cross-sectional study, and through observational studies. This would be especially important considering that accuracy and importance of perceived MC increases as children transition to middle childhood.

This thesis only examined at children at preschool ages, over one year of time, it would be important to continue to track children from early childhood to middle to late childhood through to adults to identify if there are behaviours from early childhood that influence future behaviours.

10 Conclusions

Overall, some children were not sufficiently active, as at follow-up, 30% of children were not compliant to ≥180-minutes of total physical activity (TPA), and 15% did not complete ≥60-minutes of moderate-to-vigorous physical activity (MVPA) in accordance with Study Three (page 111). Only 63% were compliant in both physical activity (PA) recommendations, at follow-up. TPA and MVPA declined overtime, and this was a significant decline in overweight children's MVPA, therefore, compliance rates must be higher to have a limiting effect on future PA compliance. There were no weight status or sex-differences in PA.

Motor competence (MC), locomotor motor competence (LC) and object-control motor competence (OC) all significantly increased over a year, apart from LC in overweight children. Sex-differences were observed in follow-up OC, where males were significantly more proficient. Similarly, males perceived MC was significantly higher than females. However, perceived MC had no mediating influence in this age group.

Associations were identified between PA in minutes and MC: TPA and MC, TPA and OC, MVPA and MC, and MVPA and OC. Furthermore, compliance of ≥180-minutes of TPA was associated with increased LC and ≥60-minutes of MVPA was associated with increased OC.

Study Three found that 96.4% of the variance in current BMI was explained by previous BMI and current MVPA. Seventy percent of current MVPA was explained by previous and current BMI and TPA, and previous MVPA and 68.3% of current TPA was explained by previous and current MVPA, current LC and current BMI. Then 27.5% of current LC was partially explained by current BMI, TPA and MVPA.

This thesis makes original contributions to the literature in British preschool aged children. Preschool ages are a critical time to investigate the determinants of childhood obesity (Dietz, 1997). This thesis contextualised aspects of the conceptual model (Stodden, et al., 2008) within this population that were not yet reported, including PA, MC and BMI. This thesis suggests that BMI and MVPA are in a reciprocal relationship with greater MVPA contributing to lower BMI and lower BMI contributing to higher MVPA. This thesis proposes that in British preschoolers enhanced LC and OC proficiency has positive associations with TPA and MVPA recommendation completion. Engaging in more TPA has positive results on MVPA participation, and higher MVPA has encouraging outcomes for BMI. The thesis included two cross-sectional studies, the first examining the associations between PA and MC, and if compliance to PA recommendations was associated with MC proficiency, the second identifying that perceived MC does not mediate the associations between PA and MC in preschoolers but suggests the mediating capacity occurs in later childhood. This study also included a longitudinal analysis to examine the contributory nature of PA, MC and BMI over a year. These conclusions are important as until the conceptual model has been empirically examined comprehensively, intervention may not be as effective.

11 References

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12 Appendices

12.1 Appendix 1: Sample Informed Consent

Thank you for considering helping one of our students with their research work. This form explains what you will be asked to do.

Information about the chosen project

The Department of Biomolecular and Sport Science at Coventry University are conducting a research study assessing the physical activity habits of preschool children in Coventry and its surrounding areas.

The children involved in the study would be asked to continue with their normal day-to-day routines. We would like to measure physical activity using an accelerometer (a watch) which they wear on their wrist for four days. We would also like to measure their height and weight and waist circumference and complete some fundamental motor skills activities (e.g. catching, throwing, jumping) with them which would be videoed. The videos would be used to slow the movement down to analyse and then destroyed.

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 not influence your child's nursery sessions in any way and could help our scientific understanding of the activity habits of preschool children. We hope you will be interested in allowing your child to participate in this project and should you have any queries please do not hesitate to get in touch.

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?

We cannot promise the study will help you personally but the information we get from this study will help improve our understanding of the influence of physical activity on health and is importance in helping develop more effective physical activity programmes that can be used to enhance children's health. Understanding physical activity and lifestyle habits may assist us in developing programmes to increase physical activity and reduce disease risk in 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 General Data Protection Regulation 2016. 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?

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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.

Please cut here and keep the information sheet for your reference.

By signing this form, you are agreeing to partake in the study. However, please note you are free to withdraw at any time.

I give permission for my child, ________________________ (insert name) to participate in the 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 and that participation is entirely voluntary.

Signed: ________________________ (Parent/Guardian) ____________ (Date)