DOCTOR OF PHILOSOPHY

Understanding fundamental movement skill development and physical activity in primary school children from different ethnic backgrounds

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Understanding Fundamental Movement Skill development and Physical Activity in primary school children from different ethnic backgrounds

By

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Dedication

I wish to dedicate my thesis to Mrs Urclin Blake, my Grandmother; a God-fearing woman of great purity, integrity and strength. Thank you for your presence, consistency and support through all things, for continually investing in me and bringing my focus back to God and His unfailing promises. I love you, Nanny, forever and always.

I would also like to dedicate my thesis to my Granddad and Grandmother, Mr Owen 'Teddy' Walker and Mrs Maria 'June' Walker. Thank you for supporting and encouraging me to keep going from the very start of my PhD and through all the added extras in life that I have experienced along the way. Your pearls of wisdom are priceless. I love you both.

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Contents

Presentation of Results

Results of the present thesis have been published in peer-review journals and presented at national and international conferences:

Study one:

- **Adeyemi-Walker, L J**., Duncan, D., Tallis, J., and Eyre, E. (2018) Fundamental Motor Skills of Children in Deprived Areas of England: A Focus on Age, Gender and Ethnicity. *Children,* 5, 110;doi:10.3390/children5080110

- **Adeyemi-Walker, L J.**, Duncan, D., Tallis, J., and Eyre, E. (2016) Fundamental Movement Skill, Physical Activity and Obesity; the PhD Journey so Far. Oral Presentation at The 2nd Assembly of the International Consortium on Motor Development Research; University of South Carolina (9-11th November 2016).

- **Adeyemi-Walker, L J.**, Duncan, D., Tallis, J., and Eyre, E. (2016) Fundamental Motor Skills proficiency of the UK child Population during early childhood and middle childhood. Poster Presentation at the British Association of Sport and Exercise Sciences (BASES) – European Federation of Sport Psychology (FEPSAC) conference 2017; England (28-29th November 2017)

Study two:

- **Adeyemi-Walker, L J.**, Duncan, D., Tallis, J., and Eyre, E. (2018) The mediating role of perceived motor competence in a child's health trajectory. Oral Presentation at the UK and Ireland motor competence networking meeting; England (January 2018).

- **Adeyemi-Walker, L J.**, Duncan, D., Tallis, J., and Eyre, E. (2018) Mediating mechanisms of children's health trajectory in practice; the role of perceived motor competence and health-related fitness. Oral presentation at BASES division of physical activity for health divisional day; England (February 2018).

Study three:

- **Adeyemi-Walker, L J.**, Duncan, D., Tallis, J., Cook, K. and Eyre, E. (2019) Fundamental Movement Skills and physical activity of primary school children in a deprived and ethnically diverse area in England: A primary school teachers' perspective. Oral presentation at the British Heart Foundation – Motor competence: The forgotten pathway to improved cardiovascular health; England (June 2019).

Study four:

- **Adeyemi-Walker, L J.**, Duncan, D., Tallis, J., and Eyre, E. (2018) Should Integrative Neuromuscular Training be implemented earlier than middle childhood? Oral presentation at the European College of Sport Science Congress 2018; Ireland (4-7th July 2018).

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List of abbreviations

BOTMP-BOT-2 - Bruininks-oserety Test of Motor Proficiency

CON – Control

CPD- Continued professional development

DfE – Department for Education

FMS – Fundamental movement skills

FMS-AT – Fundamental Movement Skill assessment tools

HRF – Health-related fitness

INT – Integrative Neuromuscular Training

KTK - körperkoordinationtest Für Kinder

LPA – Light physical activity

LF – Long form

LV – Long version

MABC-2 – Movement Assessment Battery for Children-2

MMT – Maastrichtse Motoriek Test

MOT 4-6 - Motoriktest Für Vier- bis Sechsjährige Kinder

MPA – Moderate physical activity

MVPA – Moderate-to-vigorous physical activity

Ofsted – The Office for Standards in Education, Children’s Services and Skills

PA – Physical activity

PDMS-2 – Peabody Developmental Motor Scales-Second Edition

PE – Physical Education

PMC – Perceived motor competence

SES – Socioeconomic status

SF – Short form

SLJ – Standing long jump

SV – Short version

TGMD-2 – The Test of Gross Motor Development-2

VPA – vigorous physical activity

ABSTRACT

INTRODUCTION: Fundamental Movement Skill (FMS) proficiency is low in children in deprived and ethnically diverse areas in the UK during early childhood. These skills are essential for PA engagement which is also low. Exploration of the constraints influencing the low FMS proficiency and PA engagement is limited. The thesis sought to establish prevalence, identify constraints and improve FMS prevalence in this demographic. *METHOD:* Following institutional ethical approval, children and teaching staff were recruited from six primary schools located within deprived wards in Coventry. FMS (process, product and perceived (PMC)), health-related fitness (HRF) and PA were assessed during early and middle childhood. Teachers' perceptions of the barriers and facilitators to FMS development, PA engagement and PE delivery/planning were obtained through semi-structured focus groups. The quantitative and qualitative findings collectively informed a six-week Integrative Neuromuscular Training (INT) intervention. *RESULTS:* Children in deprived and ethnically diverse areas demonstrated low FMS proficiency, with those from Asian ethnic groups and girls during middle childhood showing the poorest skills. Quantitative and qualitative constraints were identified. The association between FMS and PA was mediated by HRF but not PMC during early and middle childhood. Teaching staff mainly perceived barriers to FMS development and PA engagement within the physical and social environments while key facilitators were identified within the school environment (e.g. physical environment, staff); although it presented obstacles (e.g. lack of priority placed on PE). INT improved FMS (total and locomotor) proficiency although this was not significantly greater than statutory PE. Sprint speed improvements were only maintained in the INT-group however object-control skills, jump distance and hand-grip strength did not change. *CONCLUSION:* FMS proficiency of children living in deprived and ethnically diverse areas is low with different ethnicities, ages and sexes developing disproportionately. Constraints lie within the individual (child), task (FMS) and environmental domains that require adaptations to the statutory PE curriculum (e.g. content and time), greater than the incorporation of INT, to be overcome and improve the low FMS proficiency levels.

1.0 INTRODUCTION AND THESIS OVERVIEW

Physical inactivity is globally identified as the fourth leading risk factor of mortality (World Health Organisation 2019) with childhood physical activity (PA) levels tracking into adulthood (World Health Organisation 2017). PA is widely defined as "any bodily movement produced by skeletal muscles that result in energy expenditure" (Caspersen, Powell and Christenson 1985). The bodily movements carried out are comprised of properties that are both mechanical (limb movements produced by muscle contractions) and metabolic (oxygen availability for the contraction to be carried out) (Haskell and Kiernan 2000). Global PA prevalence has been shown to decrease by ~4.2% on average per year of age from as early as five-years-old with increases in time spent in sedentary PA (Cooper et al. 2015). When considering a specific geographical location, variances between the highest and lowest participation levels have ranged from 15-to-20% in nine-to-ten-year olds and 26-to-28% in 12-to-13-year-olds (Cooper et al. 2015). Specific experimental data assessed globally should, therefore, be considered with caution when observing childhood PA engagement in specific countries. In the UK it has been found that less than ~30% of children across each age band between the ages of two-to-12-years-old meet the UK PA guidelines recommended to promote health benefits (Owen et al. 2009, Townsend et al. 2015). The lowest engagement levels of ~10% are observed in children aged between two-to-four-years-old (Owen et al. 2009, Townsend et al. 2015). A large percentage of children are therefore not engaging in enough PA to experience the well-researched physiological, psychological and social health benefits (Janssen and LeBlanc 2010).

Engagement in PA incorporates physical literacy which is most commonly defined as a child having the "motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in PA for life" (Whitehead 2010, The International Physical Literacy Association 2014). For children to participate in PA they must develop the necessary skills to do so (Stodden et al. 2008). These skills are termed Fundamental Movement Skills (FMS) and are widely identified as the 'building blocks' that are later used to carry out skills that are more complex and specialised (Logan et al. 2017a). A thorough exploration of FMS can be found in *section 2.1*. Theoretical models of motor development (Gallahue, Ozmun and Goodway 2012) suggest development occurs in stages; by the time a child is five-to-six-years-old FMS acquisition would have occurred and a child's ability to perform these skills will be at the optimal level around the ages of seven-to-11-years, where they will begin to transition skills into specialised movements (DeOreo and Keogh 1980, Gallahue, Ozmun and Goodway 2012, Haywood and Getchell 2014). To develop these skills, children need to be taught them and have the opportunity to practice them with reinforcement (Riethmuller, Jones, and Okely 2009, Logan et al. 2012, Morgan et al. 2013). The first opportunity for FMS to be taught, practiced and reinforced to all children in England is in primary school, through the physical education (PE) curriculum (Department for Education DfE 2014, 2017). Currently, the primary school PE curriculum focuses on FMS development from the year children enter school in early childhood, aged four-to-five-years-old, to when they leave during middle childhood aged ten-to-11-years-old (DfE 2014, 2017) aligning with the expected developmental stages (Gallahue, Ozmun and Goodway 2012). The prescription and expectation of skill performance aims to progress throughout these years from children acquiring skills to performing them with full competency (Gallahue, Ozmun and Goodway 2012). Children, however, are currently performing FMS at low levels globally and in the UK, thus the ability to engage in PA may be compromised as a consequence of poor motor proficiency.

Development of FMS is influenced by constraints within the individual, environment and/or the task at hand (Newell 1986). Individual constraints may include a child not having the required strength to perform a skill, while environmental constraints may be experienced where cultural norms are not facilitative of FMS development. Constraints related to the task itself may be experienced through limited time provided for teaching and/or practicing a task. Children who therefore face more negative constraints are at a greater risk of delays in their FMS development. These constraints (i.e. individual, task, and environment) may explain the low FMS proficiency that has been observed globally and in the UK.

Children that live in low socioeconomic status areas (low-SES) are shown to have lower FMS proficiency than those living in high socioeconomic status (high-SES) areas (Foweather 2010, Foulkes et al. 2015, Morley et al. 2015). In England, a high percentage of ethnic minority groups are found to occupy deprived areas (Coventry Partnership 2010, Insight 2015b). Within low-SES groups FMS proficiency has been shown to vary between children aged five-years from different ethnic backgrounds; with children from Black, Asian and Minority Ethnic (BAME) backgrounds demonstrating poorer skills (Eyre, Walker and Duncan 2018). Prevalence of FMS in children from deprived and ethnically diverse areas that are expected to have mastered these skills (i.e seven-to-11-year-olds) is yet to be established.

Greater clarity of FMS proficiency of children living in deprived and ethnically diverse areas in England and the constraints experienced by these children is needed; particularly as PA engagement levels are low (Owen et al. 2009, Nightingale et al. 2016) and unfavourable health measures are also shown specifically within these groups (Martinson, McLanahan, Brooks-Gunn 2015). Global data currently shows a positive association between PA engagement and FMS (Robinson et al. 2015) with several interventions implemented to improve FMS (Logan et al. 2012, Morgan et al. 2013). The literature relating to FMS proficiency and improvement within children in the UK is limited; there is a scarce amount of research carried out in assessing socioeconomic differences and even less is known concerning ethnicity.

Therefore, the purpose of this thesis is to address some of the limitations within the literature regarding the poor FMS proficiency of children living in deprived and ethnically diverse areas in England. This will be the first study to identify the prevalence of FMS during early and middle childhood within these groups. The constraints that contribute to the prevalence will also be identified and explored through mixed-method approaches, which are yet to be established. This will enable a more specified approach in an attempt to change the constraints of FMS experienced by children who seem to be at greater risk of not developing expected FMS levels, through a more specific informed intervention. Exploration of FMS within these groups, identifying constraints and ultimately implementing an intervention could improve FMS; positively impacting the current low of PA engagement levels of children living in deprivation and those from BAME backgrounds.

Findings within this thesis:

1. Provide further insight into the current prevalence of FMS proficiency of children in Central England living in deprived and ethnically diverse areas.

2. Provide greater depth in the understanding of FMS and PA concerning ethnicity.

3. Provide insight into the objective and perceived constraints concerning FMS, PA and PE experienced by teaching staff and children living in a deprived and ethnically diverse area in Central England.

4. Identify the reality of the PE curriculum, PA engagement and FMS development in primary schools within deprived areas. Which in turn provides a basis for necessary developments/maintenance, if any, to be further explored.

This thesis will present findings that contribute to novel developments in identifying the prevalence of FMS and understanding why. Subsequently providing children living in deprivation with greater opportunities, to develop FMS and lead active lifestyles, facilitated within the school environment which is deemed most optimal.

2.0 A REVIEW OF LITERATURE

2.1 Fundamental Movement Skills

Motor development is a life-long progressive concept where motor behaviour changes over time (Gallahue, Ozmun and Goodway 2012). The changes occur through the interaction between the demands of the movement task, the individual's biology and the environmental conditions that the task is being performed in (Gallahue, Ozmun and Goodway 2012). Across the lifespan, motor development is comprised of four movement phases; reflexive, rudimentary, fundamental and specialised (*Figure 2.1; Gallahue, Ozmun and Goodway 2012)*. The reflexive and rudimentary phases encompass two progressive stages whereas children progress through three stages within the fundamental and specialised movement phases, as shown in *figure 1.1* and further explained in *table 2.1* (Gallahue, Ozmun and Goodway 2012). It is within the fundamental movement phase that children begin to independently navigate through their environments and engage in PA as their FMS develop (Clark 2007, Gallahue, Ozmun and Goodway 2012). As children progress through the fundamental movement phase they develop from the initial stage to the elementary stage, ending with the mature stage. Gallahue and colleagues (Gallahue, Ozmun and Goodway 2012) theoretical model for motor development (*see figure 2.1*) along with supporting literature propose the acquisition of FMS is initiated during infancy, and commonly occurs before the ages of five-to-six-years-old (DeOreo and Keogh 1980; Gallahue, Ozmun and Goodway 2012, Haywood and Getchell 2014). The vast majority of the development and improvement of these skills transpires between the ages of four-to-11-years-old, after which the performance motivation for skills is suggested to become more context-specific; transitioning into the specialised movement phase (e.g. running specifies into running over hurdles; Booth et al. 1997, Clark 2007) that can be utilised in PA.

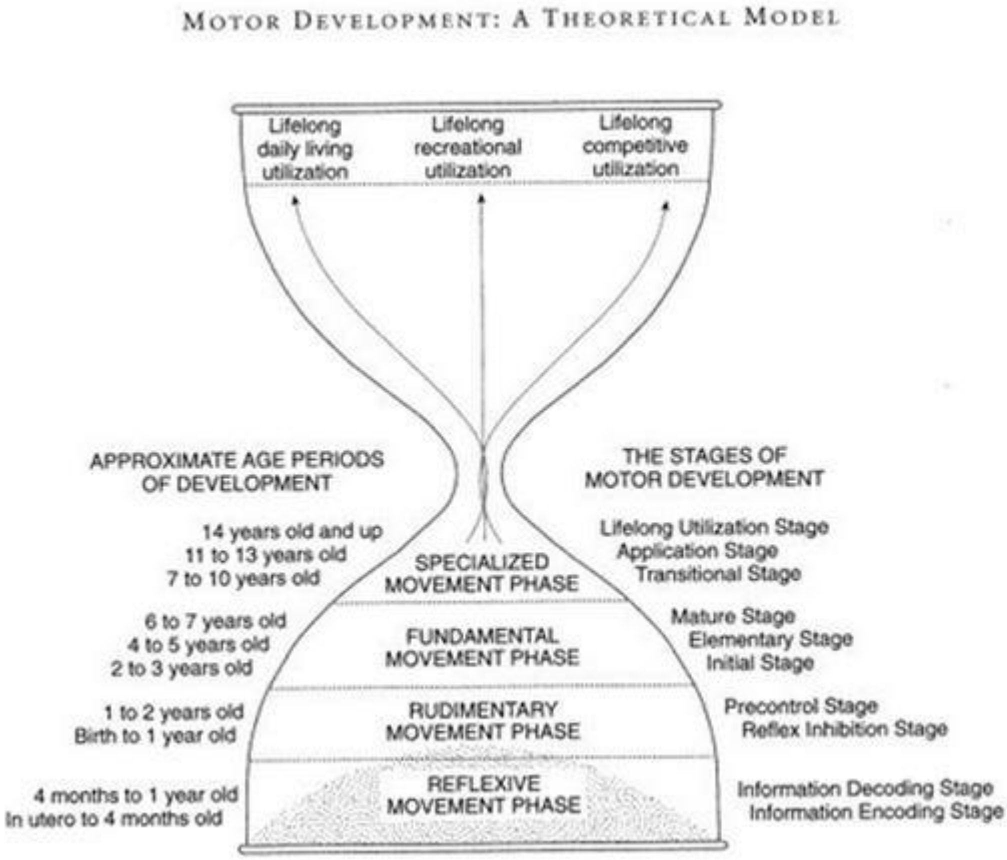


Figure 2.1. Motor development phases and stages; sourced from Gallahue, Ozmun and Goodway (2012).

Table 2.1. Phases of motor development explained (Gallahue, Ozmun and Goodway 2012)

Movement Phase	Description
Reflexive	Involuntary, stereotyped movements that are subcortically controlled; a response to particular stimuli (touch, light, sound, pressure changes). Broken down into two stages that may overlap: *1.* *Primitive refle*xes: Vital for survival; gather information through the cortical activity and development stimulation, as well as serving the purpose to nourish and protect through reflex activities such as rooting and sucking. *2.* *Postural reflexes*: The later development of reflexes, reflecting voluntary behaviour. Suggested to function as a test trial for neuromotor; stability, locomotor and manipulative mechanisms.
Rudimentary	Foundational voluntary movement that is dependent upon maturation. Categorised by a sequence that is highly predictable and resistant to change.
Fundamental	Provides the independent ability to direct one's self through their environment (Clark 2007, Robinson et al. 2015). Separated into three categories: 1. *Stability / Balance*: Require the body to be able to sense adjustments in the relationship between its parts that result in and alteration of balance; subsequently being able to appropriately achieve rapid and accurate movement responses (Pollock et al. 2000, Gallahue, Ozmun and Goodway 2012, Bagley et al. 2013). 2. *Locomotor*: Movement patterns that cause the body to travel from one locality to another including running, sliding, galloping, leaping, jumping and hopping (Loovis and Butterfield 2000). 3. *Object Control/Manipulation:* Movement patterns that cause an object to be projected, transported and/or intercepted through kicking, striking, throwing, dribbling, underhand rolling and catching (Gallahue and Donnelly 2003, Gallahue, Ozmun Goodway 2006).
Specialised	The development of fundamental patterns through refinement and combining to achieve more complex skills.

There are three main categories of FMS which are also referred to as subtests; locomotor, object control and stability/balance (Logan et al. 2017b). Locomotor skills are movement patterns that cause the body to travel from one locality to another including running, sliding, galloping, leaping, jumping and hopping (Loovis and Butterfield 2000). While object control skills include movement patterns that cause an object to be projected, transported and/or intercepted through kicking, striking, throwing, dribbling, underhand rolling and catching (Goodway and Branta 2003, Gallahue, Ozmun and Goodway 2006). Stability requires the body to be able to sense adjustments in the relationship between its parts that result in and alteration of balance; subsequently being able to appropriately achieve rapid and accurate movement responses (Pollock et al. 2000, Gallahue, Ozmun and Goodway 2012 Bagley et al. 2013). Stability skills are distinct from locomotor and object control skills however the stability/balance category of FMS is often integrated within observations of locomotor and object control skills and not assessed independently.

While the skills involved in the three categories of FMS develop from the initial stage to the mature stage, a child's ability to perform skills through this process is often referred to as their level of 'competence', 'mastery' or 'proficiency'. These terms all identify how well the skill is performed but are all accepted and used interchangeably. As each definition refers to the ability to perform a skill, understandably, terms are used interchangeably. Where competence and proficiency are used, the ability, levels are frequently presented as 'low/poor', 'moderate/average' or 'high/superior' while mastery levels are generally reported as 'non-mastery' 'near-mastery' and 'mastery'. The terminology used to identify ability is highly dependent upon the scoring system of the FMS assessment tool (FMSA-T), with some tools providing a numerical output (e.g. percentiles) and others classifying using categories (e.g. near-mastery). FMSA-T will be discussed in greater depth within *section 4.1.1*. Where pre-set classifications guide outputs, these are often derived from normative data from the country where the FMSA-T was created. The differences in terminology referring to a child's ability to perform a skill and the means through which a child's ability to perform skills are identified create difficulties in the accurate direct comparison between studies and cohorts. Additionally, as differences have been observed in proficiency levels of children from different countries (Bardid et al. 2015, Bardid et al. 2016) the use of predetermined classification should be used with caution, if at all. It is, therefore, more appropriate to utilise raw scores (i.e. the number of components achieved for each skill) to identify proficiency levels, reducing the misclassification of skills.

Irrespective of the terminology used, children are demonstrating low levels of FMS proficiency globally; which is worse than children in previous years (Booth et al. 2006, Foweather 2010, Spessatoet al. 2013, Bryant, Duncan and Birch 2014, Bardid et al. 2015, Khodaverdi et al. 2016, Bolger et al. 2018, Eyre, Walker and Duncan 2018). The development of FMS is a common occurrence for many children however attainment is in no way a natural or automatic (Riethmuller, Jones and Okely 2009, Logan et al. 2012, Morgan et al.2013). Therefore, each child develops at their own rate which is influenced by a complex combination of different components.

2.2 Mechanisms influencing Fundamental Movement Skill development

Progression through the phases of motor development is determined by a complex intertwining of influential mechanisms. Theories have been proposed exploring these mechanisms influencers and identifying that FMS are not autonomous, though many typically developing children follow similar patterns. An age-related and not age-dependent stance on FMS development is therefore presented (Gallahue, Ozmun and Goodway 2012). Models such as the triangulated hourglass model by Gallahue and Ozmun (2002; *figure 2.2*) as well as Clark and Metcalfe (2002)'s Mountain of Motor Development metaphor (*figure 2.3*) illustrate how development is expected to progress during childhood. Both models consider the impact that the task, individual and environment have on the development of FMS. Only Clark and Metcalfe (2002)'s mountain, however, considers a compensatory period which indicates that detrimental changes may occur (e.g. injury or ageing) and subsequently may impact the rate of FMS development. The compensatory period further supports that FMS development varies between individuals and is age-related rather than age-dependent (e.g. two six-year-olds may be practicing catching. One breaks their arm and does not work on the skill for 12-weeks while the other is still developing it). The compensatory period also partially accounts for what is known as a 'proficiency barrier' where FMS that are not developed to a sufficient level of proficiency, creating a barrier for the development of more complex skills (De Meester et al. 2017). Furthermore, the mountain metaphor utilises multiple 'peaks' to show multiple skills, unlike the hour-glass. This provides a visual representation that each skill undertakes its own developmental process and multiple skills can be developed simultaneously; although neither model incorporates the stages within FMS development as shown in *figure 2.1* (Initial, early and mature). Though the models vary slightly, both are founded upon the influence that the task, individual and environment have on the development of FMS which can be collectively explored through Newell's theory of constraints (Newell 1986).

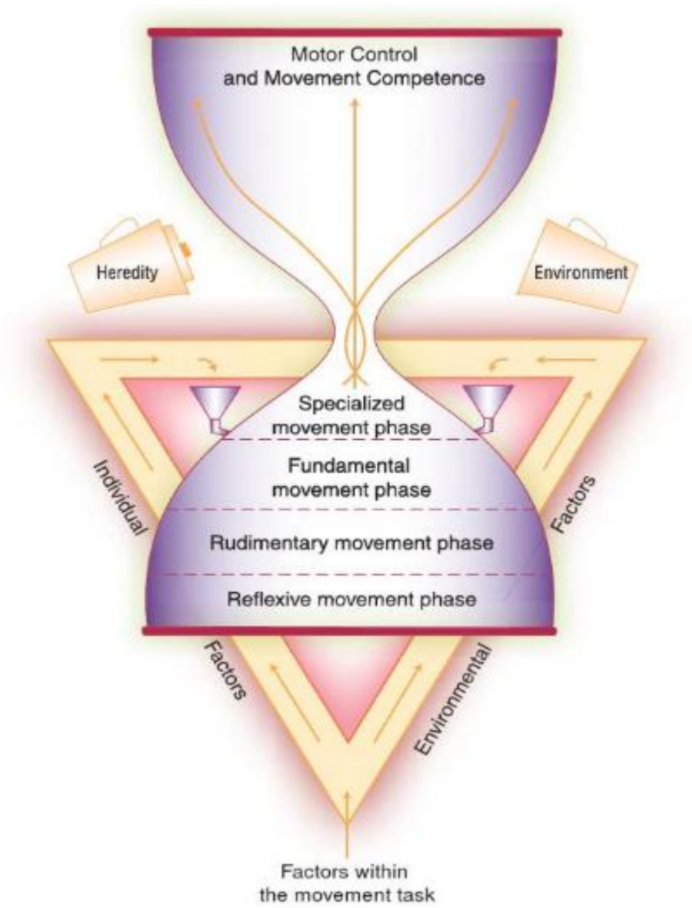


Figure 2.2. Gallahue and Ozmun's Life Span Model of Motor Development; sourced from Gallahue and Donnelly (2003).

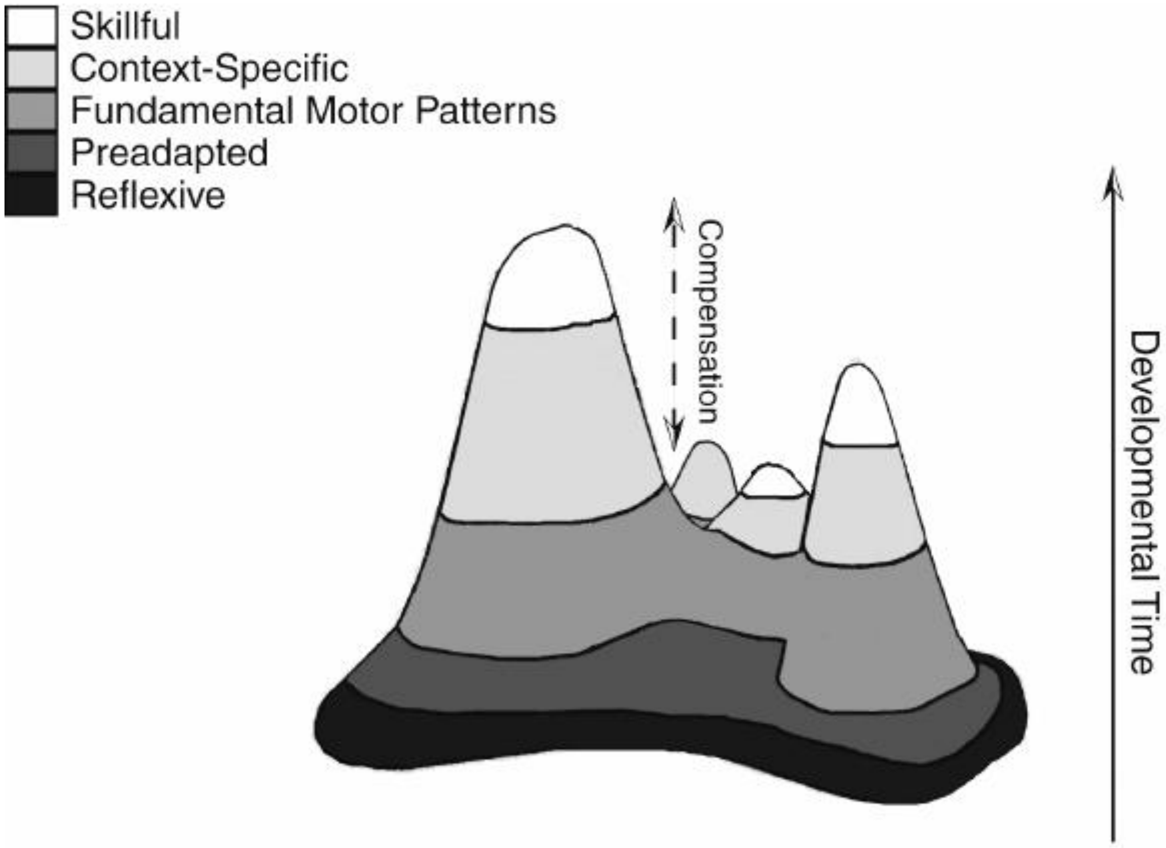


Figure 2.3. Clark and Metcalfe (2002)'s Mountain of Motor Development metaphor.

Constraints are factors suggested to influence motor development (Newell 1986). These are often identified as limiting influencers with negative impacts but can also be facilitative/positive. Within Newell's theory (Newell 1986) there are three domains of constraints categorised; individual, environmental and task (*figure 2.4*). Constraints of the individual relate to the physical and psychological capacity of the child performing the skill. The types of individual constraints include 'structural' which include the child's biological and anatomical make-up (e.g. body mass, height, body fat percentage) and 'functional' which corresponds with a child's behavioural abilities (e.g. coordination, strength, motivation, attention; Newell 1986). The constraints within the environment that the task is being performed in consider both the physical environment (e.g. space available, weather conditions) and/or the social environment (e.g. encouragement from significant others, peer interaction). Finally, constraints relating to the task being performed are identified within elements directly related such as the overall aim/goal, rules or the equipment needed for the task to be carried out (Newell 1986). Due to the various contributors within each domain and their complex nature both individually as well as how they interact with each other, the capacity to which a child's FMS development is influenced is complex and unique. As FMS are pivotal for PA across the lifespan, impacting health and well-being, it is important to identify constraints experienced by children that impact FMS development, particularly where FMS and PA are lacking. This will enable practices aiming to improve FMS to be more informed and specific through limiting constraints to be adapted/removed and facilitative constraints to be maintained. Ultimately a child's ability to engage in PA will be improved as the necessary skills required to progress.

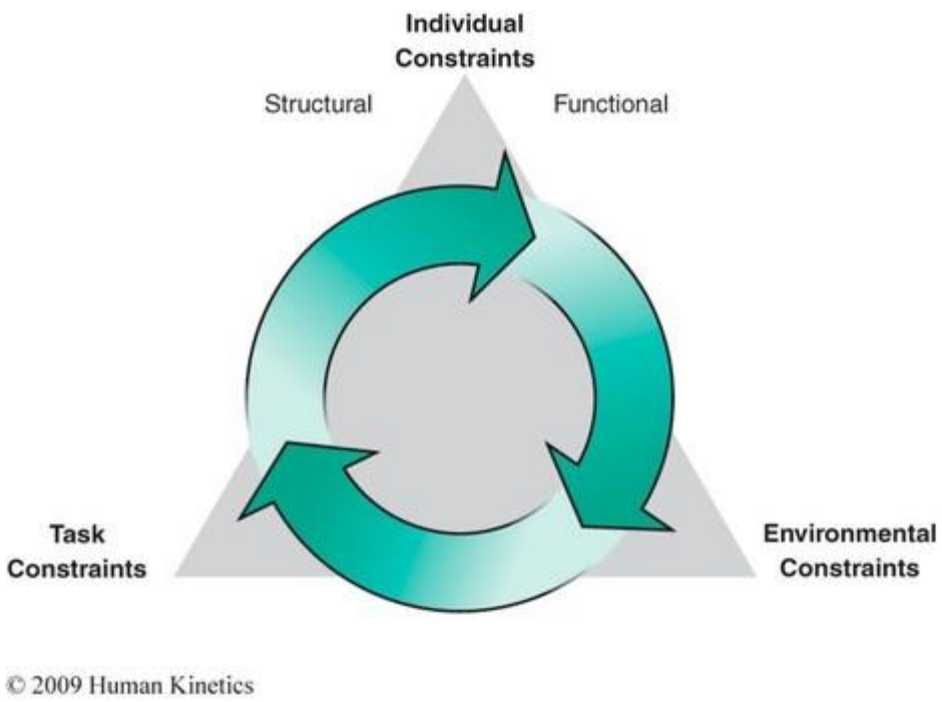


Figure 2.4. Newell's theory of constraints model (Newell 1986).

Understanding the development process and the positive impact that manipulating constraints (Newell 1986) may have is important in the pursuit of developing skills. Along with constraints, due to the voluntary nature of FMS (Table 2.1), FMS development is often linked to the need for skills to be taught to the learner, practiced by them and then reinforced (Riethmuller, Jones and Okely 2009, Logan et al. 2012, Morgan et al.2013). This consensus identifies with the theory of *deliberate practice* (Ericsson et al. 1993, 2003, 2007, 2008a), where PA is characterised by being carried out in a specialist facility involving adults to achieve a stated goal; a form of formal engagement with explicit rules and lack of enjoyment (Côté, Baker and Abernethy, 2007). The theory of *deliberate practice* concerning FMS development is endorsed through both systematic reviews and meta-analysis; which have identified the significant improvements of FMS through movement interventions across childhood and adolescence. Interventions varied in location, content and application although the majority were delivered through direct instruction. Improvements were consistent across total FMS subtests (object control and locomotor) with medium to large effect sizes (Logan et al. 2012, Morgan et al. 2013; An in-depth exploration of FMS interventions is discussed in *section 2.8*). The notion that FMS need to be taught and practiced is supported.

Moreover, there is, however, a lack of acknowledgement of the potential for children to develop their FMS through *deliberate play* theory (Côté, Baker and Abernethy, 2003, 2007). This supports the development of FMS through repetition and reinforcement of skills but challenges the need for FMS to be taught. During deliberate play, children informally engage in activities in a variety of settings of their own accord, without the requirement of an adult. The quality of the play engaged in is not pre-set and the rules are often very flexible if present at all (Côté, Baker and Abernethy, 2007). The theory of *deliberate play*, although not often directly considered when FMS development of children is referred to, broadens the possible channels that children can develop their FMS and challenges the rhetoric that FMS must be taught. Within many interventions, control groups or non-experimental groups have been shown to engage in ‘free play’ instead of the intervention regime (Logan et al. 2012). These groups have shown effects that have been non-significant (Logan et al.

2012). Therefore, although children may be able to utilise and practice skills during *deliberate play*, the elements of teaching and *deliberate practice* are vital for children to reach higher levels of proficiency.

Alongside the potential manipulation of constraints within the *individual, task* and *environmental* domains, recognising and understanding the nature of the impact determinants/correlates have on FMS development is pivotal to their improvement. Multiple factors across childhood and adolescence have been shown to influence a child's ability to perform FMS. There is a greater breadth of support for correlates/determinants concerning the *individual*; for example, much of the literature concurs that higher levels of proficiency have been shown in children that are older (age), male (sex), classified as a healthy weight, have higher cardiorespiratory fitness and those who engage in more habitual PA at higher intensities (Hardy et al. 2012, Iivonen and Sääkslahti 2014; Robinson et al. 2015). Variables within the social and physical environment have also been shown to be important in the level at which a child performs FMS, although less examined than the aforementioned factors. Where a child experiences more optimism expressed towards PA by their mother, those that have more time to freely move around as well as those who engage more with older children have been shown to have higher proficiency of FMS (Barnett et al. 2019). Additionally, children that have more PA equipment available within their home environment predicted greater proficiency in object control skills (Barnett et al. 2019).

It is important to note that correlates/determinants of FMS have been shown to differ in prominence at different ages (Barnett et al. 2019), between skill subtests and are also context-specific (Hardy et al. 2012, Barnett et al. 2013, Iivonen and Sääkslahti 2014, Barnett et al. 2019). It can, therefore, be expected that they may be different between samples. Furthermore, most tools used to assess FMS vary in their components that define object control and locomotor skills (Iivonen and Sääkslahti 2014), preventing the consolidation of findings and inhibit the comparison of research outcomes, particularly where differences have been found or where outcomes are inconclusive. Further to the differences in assessment tools used, where correlates have been observed, the contextual elements (e.g. physical and social environments) vary and therefore broaden the complexity of correlates along with the interactions between constraints experienced by children. The components observed concerning correlates and determinants of FMS vary between studies and are complex in their interactions. The difficulty is therefore caused in defining them and identifying the level/order of influence in absolution which may vary between samples and the constraints experienced by them.

2.3 Physical Activity

Engagement in PA is classified within two components; non-organised and organised PA (Okely, Booth and Patterson 2001). Non-organised PA is described as PA that has no formal leader such as a coach or instructor. Training and competitions are not formally organised or structured for participants; for example, rollerblading or pick-up ball games (Okely, Booth and Patterson 2001). Organised PA is said to be led by coaches/instructors. There are formally structured training sessions and competitions; for example PE classes, gymnastics classes or playing for a basketball team (Okely, Booth and Patterson 2001). It is within the organised component of PA that children undertake the required teaching and reinforcement of FMS although practice of skills can take place when children engage in either non-organised or organised PA.

When engaging in PA, along with the type of activity being identified as organised or unorganised there is often referral to the intensity of that activity. The intensity identifies how hard the body is working while participating in PA and represented across four main categories; sedentary, light, moderate and vigorous (World Health Organisation 2019). Sedentary activity encompasses behaviours with minimal energy expenditure while awake, such as sitting/lying down (e.g. watching television, reading, playing computer games) while activities of light intensity include those that involve standing and moving around. Moderate PA (MPA) requires more effort, resulting in an accelerated heart rate through exercises such as brisk walking, gymnastics, dancing and active involvement in games (Centers for Disease Control and Prevention 2019, World Health Organisation 2019). The most strenuous PA level is vigorous PA

(VPA) which is defined as needing a large amount of effort and results in breathing becoming rapid and heart rate to substantially increase (Centers for Disease Control and Prevention 2019, World Health Organisation 2019). Activities identified as VPA include running, participation in sports and games competitively and fast swimming (Centers for Disease Control and Prevention 2019, World Health Organisation 2019). The distinction between MPA and VPA is provided although these two categories are often combined into moderate-to-vigorous-PA (MVPA); in part due to the substantial health benefits elicited at an MPA level and uncertain findings of the added benefits of solely engaging in VPA when controlling for volume (Powell, Paluch and Blair 2011). A vast range of examples are provided by the Centres for Disease Control and Prevention and The World Health Organisation (Centers for Disease Control and Prevention 2019, World Health Organisation 2019); measures of PA to identify the intensity levels of engagement are explored in greater detail in *section 4.2*. Engagement in different intensities promotes various health benefits from childhood to adulthood (Tarp et al 2018). As such, recommendations for PA engagement levels are provided across the lifespan.

2.3.1 UK recommended physical activity guidelines for health in children

Health benefits attributed to PA engagement are well explored, with greater engagement levels at higher intensities seemingly to elicit more favourable outcomes (Tarp et al 2018). Thus the establishment of evidence-based national and international PA guidelines for children are necessary. Previous PA guidelines (*Table 2.2*) in the UK, were not provided for early years and PA engagement of moderate-intensity was suggested for school-age children. The previous recommended time spent in moderate PA was consistently maintained at 60 minutes across England, Scotland, Wales and Northern Ireland however the frequency of this engagement varied between countries; ‘each day’ vs. ‘most days of the week’ vs. ‘5 times per week’ (*Table 2.2*). Considering the lack of provision for early years and the variance across the UK, in light of the research and revised recommendations in America along with developments in Canada, the guidelines of individual countries in the UK were reviewed (Chief Medical Officer 2011).

Table 2.2. Previous minimum physical activity recommendations for children in UK countries.

	Early years	For children of school age, moderate-intensity activity:
England	Not Specified	For 60 minutes each day
Scotland	Not Specified	For 60 minutes on most days of the week
Wales	Not Specified	For 60 minutes five times a week
Northern Ireland	Not Specified	For 60 minutes each day

Following this, PA guidelines were developed (Chief Medical Officer 2011). These included newly founded recommendations for early years, greater specificity in prescription across all age categories (i.e. intensity, duration and frequency), as well as a muscle and bone strengthening elements. The current PA guidelines for health for children and adolescents (under five-to-18 years-old) in the UK (Chief Medical Officer 2011, pp.7), are as follows:

Early years (under-fives')

1. Physical activity should be encouraged from birth, particularly through floor-based play (e.g. 'Tummy time', reaching/grasping for objects, pulling, pushing) and water-based activities in safe environments.

2. All under-fives should minimise the amount of time spent being sedentary (being restrained or sitting) for extended periods (except time spent sleeping).

Early years (under-fives capable of walking)

1. Children of pre-school age who are capable of walking unaided should be physically active daily for at least 180 minutes (three hours), spread throughout the day (e.g. activities involving movements of all major muscle groups, climbing frame, riding a bike, running, chasing games, active transport).

2. All under-fives should minimise the amount of time spent being sedentary (being restrained or sitting) for extended periods (except time spent sleeping).

Children and young people (five-to-18 years-old)

1. All children and young people should engage in moderate to vigorous-intensity physical activity for at least 60 minutes and up to several hours every day (e.g. bike riding, playground activities).

2. Vigorous-intensity activities (e.g. fast running, swimming, football), including those that strengthen muscle and bone (e.g. swinging on playground equipment, hopping, skipping, gymnastics, tennis), should be incorporated at least three days a week.

3. All children and young people should minimise the amount of time spent being sedentary (sitting) for extended periods.

The current guidelines have been established for just under a decade however an expert working group have proposed several recommendations for the revision of the PA guidelines for children and young people (*Table* 2.3; Bull et al. 2010) :

Table 2.3. Physical Activity guideline recommendations for children and young people; adapted from Bull and colleagues (2010).

	Recommendation
1	The UK guidelines on physical activity for children and young people should include a recommendation for physical activity in general, an overall guideline.
2	The UK guidelines on physical activity for children and young people should recommend "daily physical activity".
3	The UK guidelines on physical activity for children and young people should recommend at least 60 minutes of moderate to vigorous physical activity (MVPA) daily.

4 The UK guidelines for children and young people should include a specific recommendation for vigorous activity (≥6-7 METS) on at least 3 days a week.

Recommendation for supporting commentary
The commentary which accompanies the guidelines should indicate that vigorous-intensity activity will form part of the daily 60-minute recommendation for children and young people.

5 The UK guidelines on physical activity for children and young people should recommend physical activity for the promotion of musculoskeletal health and flexibility at least 3 days per week.

Recommendation for supporting commentary
Physical activity undertaken to improve musculoskeletal health can be considered to contribute to the 60 min of MVPA. However, participating in 60 minutes per day of activity which exclusively focuses on musculoskeletal development cannot be considered to be fully achieving the full recommendations, as there is no aerobic component. Many activities (e.g. many sports) combine elements of both aerobic and anaerobic metabolism and can contribute in important ways to both improved cardio-metabolic and musculoskeletal health. It is important to conceptualise children's physical activity in this holistic way – especially younger children - rather than trying to quantify separate „bouts" of aerobic/anaerobic activity. The merit of developing and maintaining flexibility should also be identified as important

6 The UK guidelines on physical activity for children and young people should add a statement that additional MVPA beyond 60 minutes and up to several hours a day confers even greater health benefit.

7 The UK guidelines on physical activity for children and young people should include some explanation to convey that the recommended physical activity is above and beyond the light physical activity undertaken in the course of normal daily living (e.g. chores, hygiene, and incidental activity).

8 The UK guidelines on physical activity for children and young people should include the concept "accumulate" in describing the recommended amount of physical activity.

9 The UK guidelines on physical activity for children and young people should provide a comment for those children and young people with disabilities (as done in Scottish 2003 guidelines) to ensure the guidelines are as inclusive as possible.

10 It is recommended that the UK physical activity guidelines for children and young people do not include a specific guideline on physical activity for healthy weight gain or the maintenance of weight loss in overweight or obese children and young people; it is recommended that this be a high priority area for further research.

Recommendation for supporting commentary
The text should clarify that physical activity is important to prevent weight gain and obesity but that to date there is insufficient evidence to identify the exact amount required for optimal benefit and the issue is complex due to the confounding factors related to dietary intake and healthy weight gain due to healthy development of muscle and bone mass. At the current time, there is insufficient evidence to make a specific physical activity recommendation for either weight loss or weight management in children. Nonetheless, it is well accepted that all physical activity contributes to achieving a healthy energy balance, which in turn determines adiposity status, an important health risk.

11 The UK physical activity guidelines for children and young people should emphasise that the benefits of regular physical activity are considerable and far outweigh the low risks involved in participation.

Many of the recommendations elaborate on the current guidelines and suggest slight adaptations. These adaptations provide greater depth and specificity in light of the advancements in the scientific evidence available (Bull et al. 2010). It should be noted however that although these recommendations are presented, the current guidelines have not changed since their inception. The achievement of the current PA guidelines for health varies between individuals within the specified age ranges as shown in the subjective and objective data.

2.3.2 Physical activity engagement levels in the UK

It is difficult to determine the true prevalence of PA due to inconsistencies in PA assessments and thus many varying percentages of how active children exist. What is clear is that as in much of the world, the child population in the UK are engaging in low levels of PA with time spent in sedentary activity increasing with age (Scholes et al. 2016). There are approximately only ~21% of males and ~16% of females between the ages of five-to-15-years-old that are meeting the recommended PA guidelines for health in the UK (Scholes et al 2016). This data, however, was collected subjectively, spanning across a wide age-range and is loosely reflective of smaller age brackets assessed. Where more specific information has been provided, observations show that up to ~10% of children in the UK aged two-to-four-years-old achieve the recommended guidelines (Townsend et al. 2015). This percentage is then shown to increase to ~24% between the ages of five-to-seven-years which continues for eight-to-ten-year-old males but decreases for females within the same age bracket (~26% vs. ~16%). The decline in PA engagement is then maintained for females aged 11-to-12-years-old (~14%) and males also follow (~19%; Townsend et al. 2015). Observing specific age groups enables a more specific and clearer picture of PA engagement during childhood. Overall there is a consistent lack of children achieving the PA guidelines in the UK across childhood where percentages do not go beyond ~30%. As children pass through middle childhood (eight-to-ten-years) this is where declines in engagement seem to begin although this is not the same for males and females.

The current prevalence of PA, therefore, varies from child to child as seen in this instance by sex across different ages. Some of the data presenting the current PA prevalence is subjective and where wider age brackets have been assessed the outcomes are less definitive. Further variation is shown between different demographics which will be discussed in more detail in *sections 2.6 to 2.8*. The factors that determine PA engagement are complex and include multiple domains that vary in prominence across the lifespan.

2.3.3 Determinants of physical activity engagement levels

Multiple determinants of PA engagement have been identified (Bauman et al. 2012). These determinants are suggested to span across individual, interpersonal, environmental, regional/nation policy and global components as shown in *figure 2.5* (Bauman et al. 2012). No single determinant has been shown to take precedence but the impact may vary as they interact in a complex manner from childhood (five-to-13-years-old) to adolescence (aged 12-to-18-years-old) and into adulthood (≥18 years-old) (Bauman et al. 2012). It is important to understand the impact that determinants have on PA engagement, particularly in childhood as PA engagement levels during childhood track into adolescence and adulthood (Tammelin et al. 2014). If determinants can, therefore, be facilitated in a positive manner where possible during childhood, improvements in PA engagement that are beneficial across the lifespan may be made. Within the ecological model, however, the determinants assessed in children were limited (Bauman et al. 2012). Many of the components within the domains were assessed by a limited amount of studies and findings were seemingly inconsistent. The demographic and biological variable of sex (male) for example was observed to be a correlate across three reviews, inconclusive results were shown in two reviews while one paper reported it as a determinant and another did not report outcomes. The other three components of parental ethnic origin (white), marital status and body mass index or anthropometry were not recorded in three out of the seven reviews, showed inconclusive results in three reviews and were deemed to not be a correlate or a determinant of PA in four reviews. Within the following categories (Psychosocial, Behavioural, social and cultural) the variables considered in children were not assessed in most studies. Furthermore, where variables were assessed they were often deemed not to be correlated or a determinant of PA. The only correlates/determinants that were identified were found in sex (male) and self-efficacy.

Contrary to the lack of evidence, Sallis, Porchaska and Taylor (2000) identified several variables to be consistently associated with PA in children aged three-to-12-years-old; many of which were not observed by Bauman *et al.* (2012). These variables included sex (male), parental overweight status, PA preferences, intention to be active, perceived barriers, prior PA engagement, healthy diet, access to programmes/facilities, and time spent outdoors (Sallis, Prochaska and Taylor 2000). Identifying determinants/correlates is important in the pursuit to improve the current lack of PA engagement in children (Taylor et al. 2017). It is also vital to understand that PA engagement is complex and influenced by multiple factors that vary between different groups of children (i.e. sex, countries/areas, and ethnic backgrounds) as well as within these groups of children. It is, therefore, necessary to understand the specific constraints experienced by the children within the specific group where PA engagement is being observed and improved.

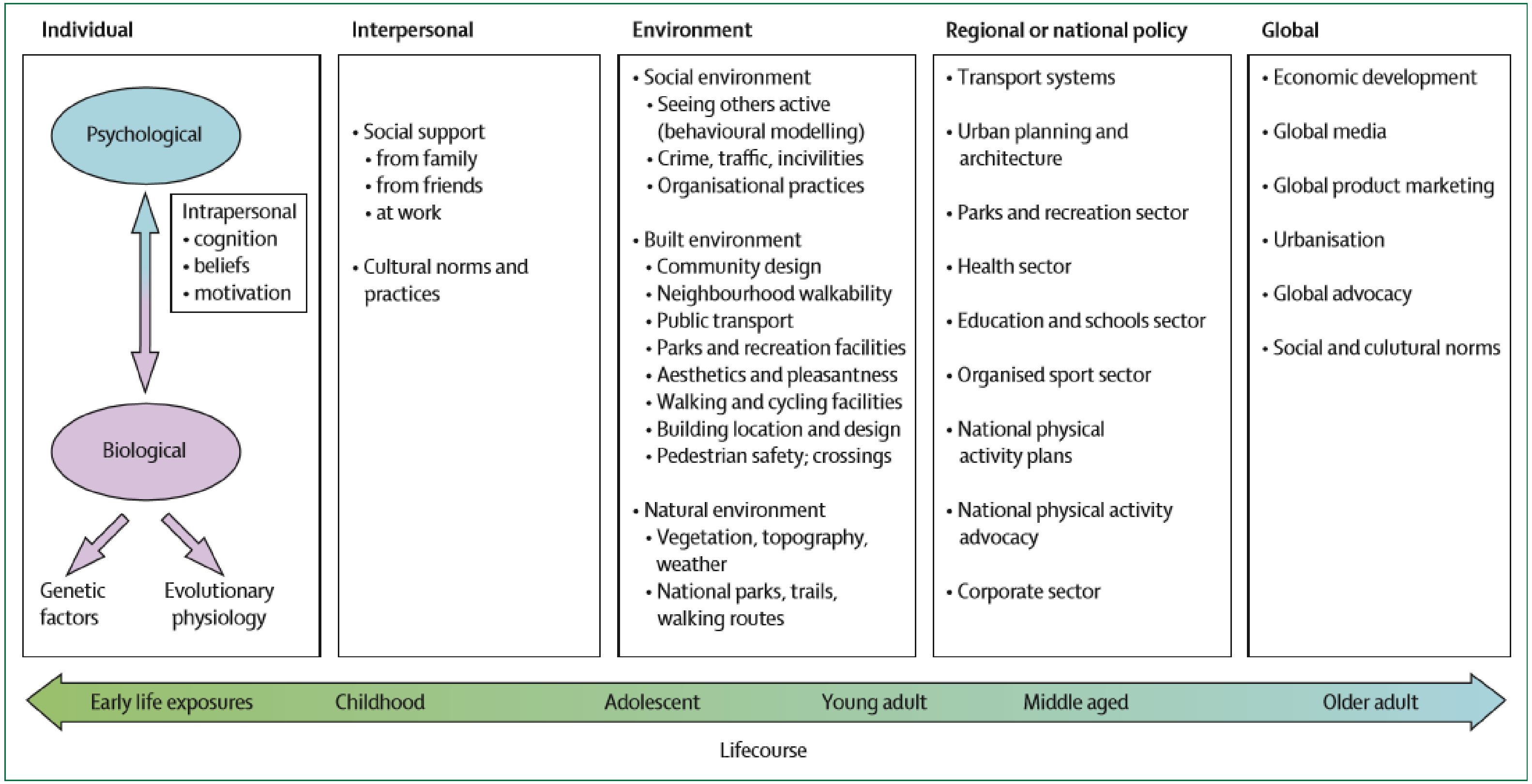


Figure 2.5. Adapted ecological model of the determinants of physical activity; Sourced from Bauman et al. (2012).

2.3.4 Physical Activity and Health in Children

Engagement in regular PA has often been shown to improve health status (Warburton, Nicol and Bredin 2006) with impacts on physical, psychological, social and cognitive health indicators in children and adolescence (Janssen and LeBlanc 2010). Primary health indicators include components such as body composition (adiposity, fat-free mass), cardiometabolic biomarkers, physical fitness (Poitras et al. 2016).

The positive impact of higher levels PA engagement is clear across primary indicators however there is less clarity when observing PA intensities. The prevalence of overweight and obese weight status is reduced in children who engage in high levels of PA and low levels of sedentary behaviours compared to low levels of PA (Saunders et al. 2016). When considering intensity levels of PA specifically, mixed views are presented. Cross-sectional studies present a non-uniform outcome of the association between PA intensity and adiposity measures (Poitras et al. 2016). While where VPA and/or MVPA have been observed in longitudinal studies, a review by Poitras *et al.* (2016) reported improvements in at least one measure of adiposity in 6 out of 10 studies. Similarly, higher levels of PA engagement overall have been found to uphold more favourable cardiometabolic risk profiles in children which was proposed to be irrespective of intensity or bout-duration (Tarp et al. 2018). Greater intensities of engagement, however, are said to be more favourable in improving cardiometabolic markers compared to lower intensity levels of PA engagement (Poitras et al. 2016). Variations between findings are also presented within and between measures of fitness and different intensities of PA across different study designs (i.e. randomised trials vs. nonrandomised trails, longitudinal vs. cross-sectional studies) (Poitras et al. 2016). Where greater amounts of PA are engaged in overall fitness measures are shown to improve but inconsistent findings are shown when PA intensity has been observed (Poitras et al. 2016). Associations between PA and primary health indicators are clear however, the exact dose/intensity is unknown.

Understanding the impact that PA has on health during childhood is important as many components contributing to a Childs' health status track into adulthood. Overweight and obsess children are at a higher risk of maintaining these weight statuses during adulthood (Simmonds et al. 2016, Singh et al 2008) leading to adverse effects such as physical morbidity and premature mortality (Reilly and Kelly, 2011). Cardiometabolic risk factors are also shown to be stable between childhood and adulthood; thus, facilitating a more positive profile during childhood would be of greater benefit across the lifespan (Camhi and Katzmarzyk 2010). Furthermore, low muscular fitness during childhood increases the risk of low muscular fitness being maintained during adulthood (Frase et al. 2017). It is therefore pivotal for health during childhood and encouraging a positive health status as an adult that the current PA engagement levels of children are tackled. Further to this ensuring that they can perform the skills necessary for PA engagement as well as understanding the relationship between FMS and PA is necessary.

2.4 Fundamental Movement Skills and physical activity

When considering the application of FMS within PA a positive bi-directional relationship has been identified between regular PA participation and FMS has been identified (Robinson et al. 2015). It is suggested that the greater the FMS proficiency, the greater the participation in PA; consequently, greater participation in PA leads to increased development of FMS, which in turn increases the likelihood of future PA participation (Okely, Booth and Chey 2004, Okely, Booth and Patterson 2001, Hirvensalo and Lintunen 2011, Vandorpe 2012).

The association between PA and FMS however, is suggested to not be exclusive. Other contributing factors such as perceived motor competence (PMC) and health-related fitness (HRF) are said to work synergistically together (*Figure 2.6;* Stodden et al. 2008)*.* These sit within the 'individual constraints' domain of Newell's theory (Newell 1986). Younger children in early childhood (one-to-three-years) are said to exhibit a weak PA and FMS relationship that strengthens over time as environmental constraints compound. The strength of this relationship is said to be greater from three-to-five-years-old and six-to-11-years-old where the vast majority of mastery is attained (Booth *et al.* 1997); peaking roughly around the age of ten-years (Booth *et al.* 1997). The relationship between FMS and PMC is also suggested to strengthen over time as a child's ability to accurately judge their ability to perform skills strengths; subsequently mediating the relationship between FMS and PA (Stodden et al. 2008). Though where children are said to overestimate their ability in the early years, it is thought that this can bring about greater PA engagement (Stodden et al. 2008). The mechanism of HRF is shown to be the least explored (Robinson *et al.* 2015). Greater developmental influence is proposed by FMS and PA on HRF during the early years which then progresses to HRF having a greater direct and indirect influence on FMS ability and PA engagement as children progress through childhood (Stodden et al. 2008). As previously discussed it must be considered that FMS are age-related and not age-dependent, thus each child will exhibit a unique rate of development although the sequence is generally the same (Williams et al. 2009). Considering that FMS are basic motor skills, a ceiling effect is suggested to have commonality with the assessment tool being used though this has not explicitly been observed.

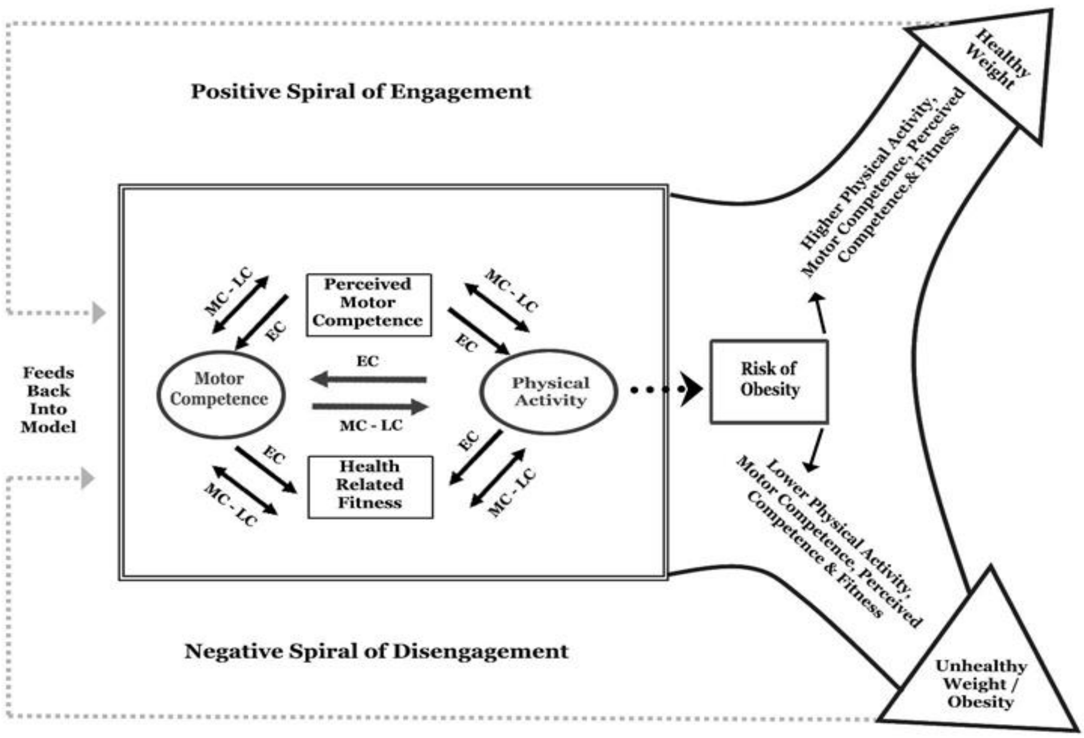


Figure 2.6. Developmental mechanisms influencing physical activity trajectories of children (Stodden et al. 2008).

The components of the model proposed by Stodden *et al.* (2008) have been explored in different capacities individually but rarely has the entire model been statistically assessed (Robinson et al. 2015). During early childhood (three-to-five-years-old) a systematic review has shown a low-to-moderate relationship between FMS and PA (r=0.16 to 0.48; Logan et al. 2015). The PA assessed to substantiate these findings was objective and recorded at an MVPA level of intensity (Logan et al. 2015). The FMS component that contributed to these overall findings was considered within individual subtests as well as total FMS (Logan et al. 2015). Slight variances between subtests were shown for example object control skills were found to have a moderate and positive relationship with PA (Hinkley et al. 2012). Where sex was accounted for, this relationship was only shown in boys and girls presented a moderate and negative relationship between locomotor skills and PA (Cliff et al. 2009). Furthermore, a study included within the review reported correlations between FMS and PA (MVPA and VPA) to be non-existent correlations in three-year-olds and positive but low-to-moderate in four-year-olds (MVPA: r = 0.26 to 0.33 and VPA: r = 0.31 to 0.41; Williams et al. 2008)). Beyond this age group during childhood, relationships between FMS and PA have also ranged from low-to-moderate. The FMS of boys aged five-to-nine-years-old are reported to be positively correlated with moderate-to-vigorous PA across all subtests (Morgan et al. 2008). Females within this age bracket showed similar reports of those in early childhood where an inverse relationship was shown between locomotor skills and MVPA (Morgan et al. 2008). However, object control skills were positively correlated with VPA (Morgan et al. 2008). Findings within children aged nine-12-years-old have shown a weak positive correlation between total FMS and MVPA as well as object control skills and MVPA (Hume et al. 2008). Locomotor skills were shown to be positive but weakly correlated with VPA in both males and females aged nine-12-years-old, with females also showing a weak correlation between VPA and total FMS (Hume et al. 2008).

The experimental data seems to suggest a low-to-moderate strength relationship between FMS and PA. There seems to be no conclusive findings as studies vary between different subtests, PA intensities as well as the age and sex of the samples. The lack of consistency within the data suggests that constraints outside of these factors may be contributing to the association between FMS and PA although these were not explored.

Direct associations between PMC within Stodden's model (Stodden et al. 2008) and PA, as well as FMS, have been investigated. Babic *et al.* (2014) identified sufficient evidence through a systematic review of a positive relationship between physical self-concept and PA in children (pre- ten-years), early adolescents (ten-to-14-years) and late adolescence (15-to-19-years). The relationship was reported to strengthen from childhood to late adolescence. It should be noted however that Babic *et al.* (2014) emphasised the need for further exploration of the relationship between PA and PMC, with regards to the mechanisms responsible. Furthermore, due to the study heterogeneity and the bias risk of the studies used being high, caution should be taken when interpreting observations. Where the association between PMC and FMS have been observed in children aged three-to-four-years positive but weak correlations have been reported across all subtests in males (Robinson 2011). Females, however, only exhibited this significant but weak correlation between PMC and object control skills; while GMQ and locomotor skills were correlated to PMC with moderate strength (Robinson 2011). In support of this, positive associations were also shown between actual and perceived competence of object control skills in both males and females in a sample aged four-to-eight-years-old (Barnett et al. 2015). Conversely, no direct associations were shown between PMC and FMS subtests in children aged three-to-six-years (Hall et al. 2019).

The association between PA and PMC as well as FMS and PMC appears weak during childhood as previously stated. Distinctive findings are unclear across each year (e.g. three-years, four-years, five-years etc.) as many of the studies collate data across the years with no clear separation defined. The weak associations are often attributed to the lack of cognitive ability during childhood, resulting in exaggerated PMC (Stodden et al. 2008). It would be useful for ages to be assessed individually or by developmental stages within the FMS development stage (Two-to-three-years; Initial stage, four-to-five-years; Elementary stage, six-to-seven-years; Mature stage, (Gallahue, Ozmun and

Goodway 2012) to provide that are more distinctive and specific than previous research.

All of the direct associations presented in the model by Stodden et al. (2008) are focused towards a positive trajectory where higher PA engagement, motor competence, perceived motor competence (PMC) and HRF result in healthy weight; or negative trajectory where lower PA engagement, motor competence, PMC and fitness result in unhealthy weight/ obesity. However, a direct association between HRF and other mechanisms is minimal. Furthermore, empirical data exploring PMC and HRF as mediating mechanisms are scarce with two studies assessing the influence of PMC on the relationship between motor competence and PA. One study observed the direct and indirect association between all four components, limiting an overall view of trajectories proposed.

The influence of PMC on motor competence and PA has been assessed in children aged three-to-six-years (Hall et al. 2019) and eight-to-12-years (Barnett et al. 2008). No direct association between FMS (locomotor, object control or total FMS), MVPA or PMC was shown in the three-to-six-year-old sample (Hall et al. 2019). There was also no significant variance between FMS and MVPA through the mechanisms of PMC (Hall et al. 2019). The experimental data within this age group supports suggestions that these mechanisms are loosely related during the early years of childhood and strengthen overtime (Stodden et al. 2008). As previously stated, the study by Hall et al. (2019), collated results of the entire sample which does not allow for consideration of the three stages within the fundamental movement phase of motor development. Additionally, FMS are required to be taught to enable them to develop (Morgan et al. 2013). Within England, each child is provided mandatory teaching opportunities through the PE curriculum (DfE 2014). These teaching opportunities are implemented from four-to-five-years and adapt after each primary school year (DfE 2014). Collating the entire sample does not consider that it is not mandatory for children aged three-to-four-years to engage informally structured PE lessons or that the teaching of FMS develops.

Therefore, although the work aligns with the model (Stodden et al. 2008), further investigation is needed to provide a greater depth of experimental support.

Mediating properties of PMC on motor skill proficiency, PA engagement and fitness (endurance) were examined over six/seven years between childhood (eight-to-12-years) and adolescence (14-to-18-years; Barnett 2008). The study highlighted that PMC mediated childhood proficiency of object control skills and adolescence PA engagement without a sex bias. Locomotor skills, however, were not a predictor of any factor measured. This was the first study of its kind and since no further research has been conducted/published publically to the researcher's knowledge. Barnett et al. (2008) suggested that PMC during adolescence was partially influenced by object control proficiency during childhood due to the strength of the direct relationship between object control ability and PMC in PA ($\beta = 0.37$) and fitness models ($\beta = 0.43$). These findings support the theoretical model (Stodden et al. 2008) with more specific insight into the longitudinal influence of PMC however, limitations are still present. This study does not assess the critical stages of motor development where FMS are firstly being acquired and developed. Children aged eight-to-12-years-old are expected to be within the specialised movement phase of motor development. However, eight-year-old children sit within the transitional stage and 12-year-old children who are no longer in primary education are expected to be applying these skills within sport-specific situations (Gallahue, Ozmun and Goodway 2012). Similarly, adolescence aged 14-years are expected to have just entered the lifelong utilization stage compared to 18-year-olds who would be been utilising FMS skills for approximately four years (Gallahue, Ozmun and Goodway 2012). Separating the assessment of outcome measures of these age groups would provide a more detailed and accurate experimental picture. Furthermore, cardiorespiratory endurance was the only measure of fitness included in the study. While this measure is valid, reliable and also considers practicality when testing within a sample of this age and size (Leger 1982), FMS are suggested to require muscle force production that is effective (Moody et al. 2014). Research including age-appropriate assessments of strength and/or power as fitness measures is therefore needed. It is also important that the mediating mechanisms of PMC and HRF are assessed within a childhood sample to provide further experimental support for the theoretical model.

Where PMC and HRF have been observed as mediating mechanisms within eight-to-nine-year-old females, both mechanisms have been shown to mediate the relationship between locomotor skills and PA (Khodaverdi et al. 2016). The HRF was measured as 'aerobic fitness' and included BMI, sit and reach test, 600-yard walk/run, curl-ups and push-ups; a broader range of components than Barnett et al. (2008), although strength/power measures were still not considered. Males were not included within this study however; the findings partially support that the associations within the model compound over time (Stodden et al. 2008). Contrary to Barnett et al. (2008) a sex bias is present within this age-group as the mediation was only present in locomotor skills (Khodaverdi et al. 2016). The need for samples to be separated into smaller age brackets to provide more specific findings is therefore suggested.

It can be seen from the limited experimental research that further investigation is required. Current findings partially support that during early childhood the mechanisms of the model are loosely associated and compound over time (Khodaverdi et al. 2016, Hall et al. 2018) and that these associations are important for PA engagement and fitness during adolescence (Barnett et al. 2008). The relationship between FMS and PA is mediated by PMC and HRF however, this seems to differ by demographical factors such as age and sex. It is therefore suggested that if changes are made within the 'individual domain', there is the potential to improve FMS and PA engagement positively. This will be beneficial within groups that demonstrate low FMS and low levels of PA engagement. Although PA engagement, motor competence, PMC and fitness are suggested to result in healthy or unhealthy weight during childhood (Stodden et al. 2008), the mechanisms have scarcely been measured in combination by one researcher. Where experimental data is provided, there is a lack of exploration across different ages, consideration of developmental stages has been minimal and strength/power measures needed for greater proficiency of FMS were not included. Furthermore, the model does not consider constraints outside of the ‘individual’ domain and the complex interactions between, providing a partial and limited picture.

2.5 Fundamental Movement Skills, physical activity and sex

During early and middle childhood, as FMS development progresses, the majority of children are in the pre-pubertal stages of maturation; therefore males and females are expected to be biologically similar (Malina, Bouchard and Bar-Or 2004). Thus, although FMS may differ across ages, based on the biological make-up of males and females sex differences should not be present in the demonstration of FMS. Investigations into the fine and gross motor skills of males and females aged 4-to-7-years-old were carried out by Morley et al. (2015) and, Venetsanou and Kambas (2016), controlling for age. Morley et al (2015) reported females to significantly excel in total fine motor skills ($p<0.01$); while males demonstrated significantly greater skill in catching and dribbling ($p<0.01$). Venetsanou and Kambas (2016) findings also presented a significant sex difference in all eight subtests assessed. Female participants demonstrated greater proficiency than their male counterparts in balance ($p<0.01$), bilateral coordination ($p<0.05$), visual-motor control ($p<0.001$), and upper-limb speed and dexterity ($p<0.001$) skills. Whereas the proficiency of male participants was significantly greater in running speed and agility ($p<0.05$), strength ($p<0.001$), upper-limb coordination ($p<0.001$), and response speed ($p<0.05$). Where gross motor skills in the form of FMS have been assessed in children aged four-years-old, males proficiency was greater in object control skills while their female counterparts prevailed in locomotor skills ($p<0.05$; Hardy et al. 2010). It should be noted that when skills were assessed individually, significant sex differences were not present in the catch ($p=0.6$) and were only present in the locomotor skill of the hop ($p=0.01$). Observations of FMS in children aged seven-to-11-years-old, females demonstrated greater proficiency in locomotor skills compared to their male counterparts ($p=0.03$) while males were more proficient in object control skills ($p<0.001$; Barnett et al. 2009). In partial support of this, where children aged 9 to 12 years have been observed, males exhibited more proficient object control skills than females (p = 0.001 to 0.004; Hume et al. 2008, Barnett et al. 2010). However, unlike previous findings (Barnett et al. 2009, Hardy et al. 2010), a sex bias was not reported in locomotor-based skills

(Hume et al. 2008, Barnett et al. 2010). Overall in the early years of childhood males seem to prevail in object control and strength-based skills while females tend to perform better in locomotor and balance-based skills. This seems similar during middle childhood although the sex difference in locomotor skills has varied between studies. It is hard to substantiate findings due to the differences in criteria included within FMSA-T used (*see Table. 4.4*) limiting direct comparisons between studies. As sex differences are not expected based on biological differences, greater focus is drawn to constraints related to other individual components as well as the task and environmental domains. It is therefore important for sex to be considered when assessing FMS within all age groups as constraints, particularly as environmental and task constraints, outside of the individual domain, can vary substantially.

2.6 Barriers to Fundamental Movement Skill development and physical activity engagement

Children from socioeconomic backgrounds classified as deprived experience an increased risk of obesity (Newton, Braithwaite and Akinyemiju 2017), engage in greater amounts of sedentary activity (Falconer et al. 2014) and are shown to have lower proficiency of FMS (Hardy et al. 2012).

A significant positive association is proposed between SES and the proportion of FMS achieved by Australian children in middle childhood (six-to-eight-years-old; Okely, Booth and Chey 2004). Complimentary to this Hardy et al. (2012) reported low object control proficiency prevalence in boys aged seven years old to be twice as likely in low SES in comparison to peers of high SES. Elementary school girls were twice as likely to have low vertical jump proficiency if of a low-SES (Hardy et al. 2012). The measure of SES includes a combination of economic, social as well as work statuses often measured through income/wealth, education and occupation thus comparison of SES across countries should be considered with caution (Psaki et al. 2014). In the UK 22% of people are living in deprivation after housing costs have been accounted for with children accounting for 30% of this overall 22% (McGuinness 2018). The first study in England assessing FMS concerning SES found that children aged five-to-six-years-old in low-SES areas demonstrated significantly less proficient

FMS than those in high-SES areas, with a large effect size (Morley et al. 2015). When controlling for age, compared to children of high-SES, fine motor skills (line, circle, precision total, manual dexterity and fine motor total) and gross motor skills (speed/agility, press-up and gross motor total) were demonstrated with less proficiency in children from middle and low-SES (Morley et al. 2015). Literature comparing children of different SES' in England is lacking but studies conducted in deprived areas of England report low levels of FMS proficiency among children aged three-to-five-years-old (Foulkes et al. 2015, Eyre, Walker and Duncan 2018); aligning with comparative global findings. As previously discussed, FMS are utilised within PA. Therefore, if children from low-SES backgrounds have lower FMS proficiency, the PA they engage in may also be impacted as environments where PA is engaged in, FMS is provided with the opportunity to be practiced; necessary for FMS development (Riethmuller, Jones and Okely 2009, Logan et al. 2012, Morgan et al. 2013).

Less MVPA (-2.6%), VPA (-3%) and MVPA (-4%; $p<0.001$) engagement has been observed in children aged six-to-11-years-old living in low-SES areas in France compared to children living in high-SES areas (Baquet et al. 2014). Sex difference were also identified; MPA, VPA and MVPA engagement was greater in males from high SES backgrounds (+4.0%, +4.3% and +7.7% respectively, $p<0.001$) and girls exhibited this significance in time spent in MPA and VPA (+1.7%; $p<0.001$ and +2.0%; $p<0.001$ respectively) in comparison to boys and girls from low SES backgrounds (Baquet et al. 2014). Conversely, Kelly et al. (2006) reported no significant difference in PA engagement levels between four-to-five-year-old children in low and high SES areas of Scotland. It was suggested that the proposed association between obesity risk and SES may be related to diet as opposed to PA engagement. Literature suggests that there are a domain and context specificity regarding environmental influence on PA engaged in (Owen et al. 2009, Giles-Corti et al. 2005, Spengler et al. 2011). Thus, the geographical location of literature should be considered when applying findings as PA engagement levels differ between countries and regions (Griffiths et al. 2013).

Obesogenic behaviours including both low level of PA, unhealthy dietary behaviours and excessive screen time have been examined in 2773 children in England aged four-to-five and ten-to-11-years-old (Falconer et al. 2014). Low PA engagement was exhibited by 64% of the entire sample, while excessive screen-time was engaged in by 49% and over half of the participants' dietary behaviours were deemed unhealthy (Falconer et al. 2014). An association was made between these obesogenic lifestyle behaviours (individually and as a whole) and participants living in more deprived areas as well as those from Asian or Black ethnic backgrounds (Falconer et al. 2014). In Coventry, a deprived area of England, 58% of children aged seven- to-nine- years-old were observed not to meet the PA recommended guidelines for health in the UK (Eyre et al. 2015). Significantly more time was spent in MVPA in outdoor environments than indoor environments (Eyre et al. 2015). The 42% of children that did meet the recommended guidelines achieved these in school (43%), at home (20%), playing outside (street/garden; 23%), and through active travel (walking one journey; 14%) (Eyre et al. 2015). Therefore, the outdoor and school environments are presented as the most facilitative for children to engage in PA and practice their FMS although recommended guidelines are not being met.

2.6.1 Physical activity and Outdoor environments

The amount of public open spaces such as playgrounds and recreation facilities vary in communities of low and high SES (Crawford et al. 2008). Thus, similar opportunities for children to engage in PA outdoors may be present in some low and high SES communities. However, parks that have greater amenities (e.g. drinking fountains, public toilets, picnic tables) (Kaczynski, Potwarka and Saelens 2008) and are perceived to be fun, challenging and age-appropriate, facilitate greater child PA engagement compared to those that are not (Veitch et al., 2005). Thus, suggesting structures within the outdoor environments as contributing factors to the level of PA engaged in; providing greater opportunities for children to practice FMS. Although similarities in the number of public open spaces in low-SES and high-SES communities may exist (Crawford et al. 2008), areas of low-SES have been observed to have significantly fewer amenities within the public open spaces compared to high-

SES areas (Crawford et al. 2008). Unfortunately, Amenities within the outdoor environment were not recorded by Eyre et al. (2015) thus limiting the scope of the study. Consequently, the extant literature suggests that children living in low-SES areas are at a disadvantage as PA engagement and FMS practice will be negatively impacted due to the objective environment.

As well as the objective environment, the perceived environment has been associated with PA engagement (Ding et al. 2011). Parents have been found to be less encouraging and supportive of PA engagement where environments are perceived as unsafe (Allender, Cowburn and Foster 2006), restricting their child's PA engagement in such environments (Allender, Cowburn and Foster 2006, Eyre et al. 2014). Perceptions of an unsafe environment are greater where children are living in areas of greater deprivation (Murry et al. 2006). Therefore, in addition to the constraints within the objective environment, children living in deprived areas also face greater constraints with how the environment around them is perceived; placing limitations on their engagement in PA and their time to practice FMS to develop them.

2.7 Ethnicity, physical activity and Fundamental Movement skills

The ethnic make-up of the most deprived 10% of neighbourhoods in England mainly consists of people from BAME backgrounds (Jivraj and Khan 2013, Ministry of Housing, Communities and Local Government 2015). Children living in the UK from South Asian backgrounds engage in less PA and have the greatest percentage of children failing to meet recommended guidelines, compared to their Black African-Caribbean and White European counterparts (Owen et al. 2009, Duncan et al. 2012, Bhatnagar et al. 2016), despite earlier observations of some regional PA engagement disparities within the UK (Griffiths et al. 2013). These low levels of objectively measured PA engagement in children are associated with greater levels of adiposity and cardiac metabolic risk profiles (Owen et al. 2009). Furthermore, associations between obesogenic lifestyles are three times more likely in Asian and Black children than White children even after adjusting for deprivation (Falconer et al. 2014).

In the UK, a greater percentage of children from Black and Asian ethnic groups are classified as overweight/obese in comparison to their White European counterparts (Falconer et al. 2014). Graf et al. (2004) reported children in early childhood, classified as overweight and obese to have a decreased development of gross motor skills and endurance performance than their normal-weight counterparts. The progression through the development of FMS through early childhood to middle childhood (six-to-ten-years) has been reported to be more advanced in children of normal weight compared to children classified as overweight and obese (D'Hondt et al. 2013). Weight status is proposed to be a precursor and/or consequence to a child's ability to perform FMS (Robinson et al. 2015). As children reach middle childhood more advanced FMS are two to three times more likely to be demonstrated by normal weight males and females in comparison to children that are their overweight and obese counterparts (Okely, Booth and Chey 2004). Though associations between FMS and weight status have been observed, ethnicity was not accounted for in these studies.

Considering the association ethnicity is shown to have with physical activity, FMS and weight status as well as weight status and ethnicity, the literature lacks exploration of FMS concerning ethnicity. Eyre et al. (2018) conducted the first study observing ethnic differences in FMS proficiency. Children aged five-years-old from South Asian backgrounds demonstrated poorer proficiency in total FMS and locomotor skills compared to their White European or Black counterparts (Eyre, Walker and Duncan 2018) while controlling for weight status as identified by body mass index. The lower proficiency indicates that children from South Asian backgrounds experience greater negative constraints than their Black and White European Counterparts, though the constraints specific to these groups are yet to be examined. Ethnicity has not been observed beyond this age group although this is pivotal considering that FMS are expected to progress from early childhood, so where children of BAME backgrounds are already delayed this may negatively impact their mastery of skills. Furthermore, as these skills are required for PA participation and children from BAME backgrounds engage in less PA across childhood. Exploring FMS proficiency levels between children from different ethnic groups beyond 5-

years-old will provide a more comprehensive insight into the current prevalence as well as inhibiting constraints.

Children living in low-SES areas and those from BAME background are currently demonstrating poor proficiency of FMS and reduced amounts of PA engagement due to a range of constraints. Thus, to improve FMS and potentially PA tackling the constraints within these populations are key, particularly as FMS are not autonomous but need to be taught to the learner, practiced and then reinforced (Riethmuller, Jones and Okely 2009, Logan et al. 2012, Morgan et al. 2013).

2.8 Fundamental Movement Skills interventions

Proficiency of FMS is directed by teaching, practice and reinforcement as well as the combining of cognitive processing, correct FMS patterns and effective force production of the muscles (Moody et al. 2014, Payne and Issacs 2017). Thus, children's learning experience of FMS must encompass opportunities to learn a variety of generic and basic movement patterns, as well as opportunities to develop the necessary strength for these patterns to be executed efficiently at low metabolic cost and safely with minimal injury risk (Lloyd and Oliver 2012). An environment that facilitates such a learning experience has been highlighted in PE lessons based in schools (Naylor and McKay 2009, Inman et al. 2011). The PE curriculum in England entails guidelines that are mandatory and explorative, focusing on children being able to demonstrate and use FMS independently as well as in combination with each-other (DfE 2013). Further to this, children are expected to develop their control, balance, flexibility technique and strength through PE (DfE 2013). The levels of proficiency expected are guided by developmental phases associated with age. However, children in England have been found to demonstrate a low-performance ability of FMS (Eyre et al. 2015, Foulkes et al. 2015), thus focus is drawn to interventions to improve FMS proficiency. Logan et al. (2012) and Morgan et al. (2008) show numerous interventions in pursuit of improving FMS performance in the child population, however, there is limited experimental data within deprived and ethnically diverse groups in England. Multiple methods have been used in application and assessment of motor skills, the majority of which have been found to improve FMS in varying magnitudes. The ability to compare studies is challenging due to the varying approaches.

An earlier meta-analysis was carried out by Logan et al. (2012) summarising a total of 11 studies which satisfied the inclusion criteria; Implementation of any type of motor skill intervention, pre- and post-qualitative assessment of FMS competence as well as the availability of means and standard deviations of motor performance. Interventions were conducted in a range of different settings and structures (e.g. PE lessons, after school clubs, community-based) and the majority significantly improved proficiency of FMS were measured by the TGMD (2). Effect sizes ranged from d = 0.08-1.5, with the majority presenting with ≥moderate, and were deemed significant [$d = 0.39$; $n = 25$; $P < 0.001$; 95% confidence interval (CI) 0.23, 0.51]. Furthermore Logan et al. 2012), highlighted the similarities in locomotor and object control skill improvements post-intervention ($d = 0.45$; $n = 9$; $P < 0.001$, 95% CI 0.2, 0.7 and $d = 0.41$; $n = 12$; $P < 0.001$; 95% CI 0.27, 0.55, respectively). Interventions aiming to improve FMS are seemingly beneficial and fit for purpose.

However, there are limitations, when considering the content of the study closely (Logan et al. 2012). Firstly, only one of the studies that met the inclusion criteria (Ignico 1991) was conducted on typically developing children. The specific results and magnitude of improvements must, therefore, be considered with caution. Children that exhibit a risk of developmental delay, present an increased opportunity for development magnitude, thus the specifics of the results and effect sizes are not representative of the child population developing within the expected ranges. Secondly, Logan et al. (2012), reported the study by Ignico et al. (1991) to include a sample size of 30 (15 intervention and 15 control group), with results presenting a small effect size of the intervention group ($\eta^2 = 0.33$). However, due to the lack of comparative literature in the meta-analysis, these findings alone present the little but significant impact of interventions on FMS. Furthermore, only six of the studies included presented data with control groups. Within these six studies, only one study reported a significant difference in locomotor and object control skills in the control group between pre-to-post (Goodway and Branta 2003). Due to the limiting factors of the meta-analysis and particularly that participants with developmental delays were included, the improvements in FMS observed in primary school children can be applied to other literature but consideration of the effect sizes should be compared with caution.

The studies included were conducted throughout six-to-12-weeks. Interestingly Logan et al. (2012) reported no significant correlation between pre-to-post FMS improvement effect size and intervention duration (in minutes; p=0.296). Thus, it can be suggested that there is no specific implementation period of which intervention should be employed (minutes) (Robinson 2017). In the UK the academic year runs across a three-term structure in most schools which is split into six half-terms of ~six-weeks. Within the six half-terms, the areas of focus within the curriculum are often rotated, thus the PE curriculum topic changes approximately every half-term. Children are therefore provided with roughly six-weeks of instruction on different FMS which is often achieved through sporting scenarios. Only one intervention was implemented over a similar time of six-weeks (Martin *et al.* 2009) however in total 30x30 minute sessions took place and the number delivered per week were not identified. Children in the UK currently receive up to two PE lessons per week, which would result in a maximum of 12 sessions over a six-week half-term. Thus, although many of the interventions were deemed successful, the ability to integrate them into the PE curriculum in England is questionable. Furthermore, as children in England are being provided with instruction and opportunities to practice FMS through PE, yet proficiency is low (Foweather 2010, Foulkes et al. 2015), input from staff developing and delivering the PE curriculum may be pivotal in highlighting the barriers experienced.

Further to Logan et al. (2012), Morgan et al. (2013) conducted a systematic review and meta-analysis focused on purely FMS of children aged ≥five-years who were not from special populations (e.g. children with disabilities such as cerebral palsy or identified as having developmental coordination disorder or conditions such as mental illness). Similarly, significant improvements of ≥1 FMS was reported for all studies; overall FMS scores were seen in 12 studies, improvements in locomotor skills were seen from 12 and ten presented improvements in object control skills (Morgan et al. 2013). The systematic review and meta-analysis utilised more specific exclusion criteria compared to Logan et al. (2012), providing a more streamlined assessment of FMS interventions. The combination of studies included by both Logan et al. (2012), and Morgan et al. (2013) further highlighted the limitations within this research area. Of the 22 studies included only 14 used a valid tool for assessing the FMS proficiency in a primary school setting (*Table 2.4*). Concerning assessment tools, five of the studies that showed improvements in outcome measures did not use the TGMD(2) thus producing an inability to conduct a conclusive comparison with the majority of the other studies (Ericsson 2008, Salmon et al. 2008, Sollerhed et al. 2008, Kalaja et al. 2012; *Table 2.4*). Further to this, only three studies provided quantifiable results by reporting effect size, with only one utilising the widely used TGMD-2 (Martin et al. 2009) thus where improvements were shown the size of the differences were not reported. As multiple interventions were shown to positively impact FMS the limited reports on effect size do not allow for the magnitude of the changes to be compared; thus, identifying the most effective intervention is inhibited.

Table 2.4. Description of FMS interventions carried out with typically developing populations in primary school settings; adapted from Morgan *et al.* (2013)

Ref	Sample	Approach	Provider	Duration	Content	FMS assessment tool	Effect size	Post-tests & follow up duration	Significant increase (y/n)	Results
Akbari *et al.* (2009)	*N*= 40 boys, aged 7-9y. INT mean age 7.8 ± 0.99, CON mean age 8.2 ± 0.99 Iran	Direct instruction	Unclear	8wk/1440 min: 3 x 60 min/wk.	INT (1) Warm-up (2) Traditional games, culturally appropriate and relevant for Iran with multiple skills practice for both LM and OC (3) Cool down CON Activities such as football, computer games, cycling etc.	TGMD-2	Not reported	PT: 8 wk FU: None	Y	INT>CON for GM, LM and OC (p<0.001).
Bakhtiari *et al* *(2011)*	*N*= 40 girls, mean age 8.9 ± 0.5y Iran	Direct instruction	Unclear	8 wk/1080 min: 3 x 45 min/wk	INT: specific lessons plan with 3 components. (1) Heating (2) Selected exercise (3) Cooling CON – not described	TGMD-2	Not reported	PT: 8 wk FU: None	Y	INT>CON for GM, LM and OC (p<0.001).
De Araujo *et al.* (2012)	*N*= 41 boys (61%) and girls (39%) Aged 9-11y	Unclear	PE Teacher	Not reported	3 x extreme sports weekly classes (including skateboarding, roller skating, climbing, parkour activities) and	TGMD-2	Not reported	Not reported	Y	INT>CON for LM (p<0.05).

	Brazil				2x week PE classes CON 2x weekly PE classes					
Ericsson (2008)	*N*= 152 (INT x2) and 99 (CON) aged 6y Sweden	Hypothetic-Deductive	PE Teacher	3 y	INT: 3 x PE and 2 x PA at local sports clubs per week. 1x 45 min/wk additional lesson if necessary CON: 2 x 90 min/wk PE lessons.	MUGI observation checklist	2y: 0.24 (Crame´r 's index) moderate Y3: 0.37 (Crame´r 's index) large	PT: 2 and 3y	Y 2y	2y: INT>CON (*p*<0.05) 3y: INT>CON. Greatest in variable balance/bilateral coordination
Kalaja *et al.* (2012	*N*= 446 (INT: 199, CON: 247) boys (48%) and girls (52%) aged ~13 y Finland	INT: Mastery climate CON: Direct Instruction	PE Teacher (INT: 2-10 y experience CON: 5-15 y experience)	33 wk/ 825 min	INT: 25 min FMS sessions prior to regular PE lessons. CON: 1 x 90 min/wk PE lesson.	Flamingo standing test, rolling test, leaping test, shuttle run test, rope jumping test, accuracy throwing test, figure 8 dribbling test.	Eta^2 values ranging from 0.00 - 0.04 therefore considered small across all measures.	PT: 10 months FU: 17 months	Y	PT: INT>CON for flamingo standing test (*p* = .001), rolling test, balance skill sum score, and movement skills sum score (*p* = .000). FU: INT>CON for flamingo standing test (P = .046) and

										balance skill sum score (P = .014).
Karabourniotis *et al.* (2002)	*N*= 45 boys (53%) and girls (47%) mean age 6y and 6 mo. Greece	INT: Movement exploration (mastery/self-testing) CON: Direct instruction	PE specialist	12 wk/ 960 min	INT: 2 x 40 min/wk experimental movement skills curriculum (increasing time spent on self-testing activities; FMS, sports skills, fitness activities, activities with small and large equipment) CON: PE lessons (space and time perception activities; visual-motor coordination activities; static and dynamic balance; sideways movement).	TGMD	Not provided	PT: 12 wk	Y	PT: INT>CON for total GM, LM and OC (p <0.001).
Martin *et al* (2009),	*N*= 64 boys (47%) and girls (53%) mean age 5.7 y, and 5.4 y for INT and CON respectively.	INT: Mastery motivational climate. CON: Low autonomy climate	INT: Researcher/PE specialist (6 y experience) CON: PE specialist	6 wk / 900 min	(1) 3-5 min intro (2) 22-25 min skill instruction and practice (3) 2-3 closure INT: 30 mins: free movement through FMS stations differing in difficulty. Individual effort	TGMD-2	LM: time η^2 = 0.32 group x time η^2 = 0.34 OC:	PT: 6 wk	Y	INT>CON for LM and OC (p = .001)

	United States		(8 y experienc e)		and progress feedback from teacher in private. CON: skill drills, sport skills and large group activities. 30 x 30min lessons.		time η^2 = 0.45 group x time η^2 = 0.34			
Mitchell *et al.* (2013)	*N*= 701, aged 5 – 12 years New Zealand	Not provided	INT: Class teachers	6 wk	INT: PE and fitness classes. Material sourced from Kiwidex and SPARC, Developing Fundamental Movement Skills manuals to develop targeted PE plans. After baseline assessments, children set their own goals for skills they wanted to improve.	TGMD-2	Not reported	PT: 6 wk	Y	PT: INT: significant improvement in all skills (p <0.003).
Salmon *et al* (2008),	*N*=306 boys (49% and girls 51%). Mean age 10y 8 mo Australia	INT: Games and skills drills CON: not provided	INT: PE specialist	9 mo / 855 min:	INT 1: 19 x 40 – 50 mins classroom delivered lessons. INT 2: 19 x 40 – 50 mins FMS mastery lessons; run, dodge, vertical jump, throw, strike, kick. Emphasising on oyment and fun through games and maximum involvement for all children.	Department for Education Victoria Fundamental Motor Skills: A Manual for Classroom Teachers (locomotor: dodge, sprint run, vertical jump; object	Not reported	PT: 9 mo FU: 12 mo	N	PT and FU: No significant intervention effects on FMS z-scores. Adjustments/eff ects by group and gender: higher average FMS z-scores in FMS girls > CON girls (p<0.01)and

					INT 3: combined INT 1 and INT 2. CON: PE curriculum.	control: overhand throw, 2-handed strike, kick)				BM/FMS girls>CON girls Some group 3 ($p<0.05$).
Sollerhed *et al.* (2008)	*N*= 132 boys (55%) and girls (45%) aged 6 - 9y. Sweden	Not provided	INT: PE specialist and class teacher CON: class teacher	3 y/ 10,560 min/y	INT: 4 x 40 min and 1 x 60 min outdoors PA / week (increased PE time). One lesson was gender specific and the other was mixed. Children classified as obese could participate in 1 extra lesson per week. CON: PE curriculum 1 x 40 min/week for children aged 6-9 y. 2 x 40 min/week for children aged 10 – 12y.	EUROFIT	Not reported	PT: 1 y, 2y, and 3y.	Y	PT (3y): INT>CON for motor skill index ($p = 0.01$).

Interventions are beneficial for the improvement of FMS. Although several studies have reported these benefits, it is hard to compare studies and implement interventions based on literature accurately due to the gaps and lack of consistency within the research. Interventions are employed within several different environments (i.e. after school clubs, PE lessons, within the community), delivered using various approaches (e.g. direct instruction, child-facilitated) and by a range of different facilitators (e.g. researchers, parents, students, PE specialists). There is a lack of information provided regarding specifics of the intervention; duration (weeks, days per week, minutes per session), time period breakdowns of each session (warm-up time, instruction time, practice time, cool downtime), reps and sets of each exercise/skill. Various methods are used to assess FMS and motor development inhibiting the ability to accurately compare results. Furthermore as previously discussed the effect size of improvements are not discussed in abundance within the literature; thus although significant improvements have been seen these cannot be compared appropriately. The positive impact of interventions on improving FMS are evident however the discrepancies within the literature require further investigation. This is particularly important in populations where low FMS proficiency and low PA engagement levels are exhibited such as children living in deprive and ethnically diverse areas in England if improvements are to be made.

A relatively new approach that has also been explored in England to improve both the process learning of FMS as well as the required strength of children simultaneously has been found in Integrative Neuromuscular Training (INT) programmes (Faigenbaum 2011, Duncan, Eyre and Oxford 2017). INT programmes are designed to improve FMS competency by cultivating the mechanics within the movement and increase one's confidence in their physical ability (Myer et al. 2011, Moody et al. 2014). Individuals are provided with training that includes a broad variety of exercises of different difficulty levels as well as having appropriate recovery periods (Myer et al. 2011). There is no one set programme for INT however the experimental data surrounding this particular training method provides a prescriptive outline for implementation that can be adhered to; increasing the consistency within interventions and subsequently making outcomes more comparable.

Faigenbaum et al. (2011) conducted an INT intervention with children aged seven-to-eight-years. Sessions were carried out in the first 15 minutes of each PE lesson, which occurred twice per week over eight weeks, including bodyweight exercises as well as those using a durable punch balloon (Faigenbaum et al. 2011). INT was shown to be sufficient in promoting greater cardiorespiratory fitness, muscular strength/endurance and lower body power when carried out alongside regular PE lessons (Faigenbaum et al. 2011). Cardiorespiratory fitness improvements may benefit overall health trajectories (Stodden et al. 2008). Though Faigenbaum et al. (2011) demonstrated improvements in strength, which is a necessary element in the performance ability of FMS (Lloyd and Oliver 2012), FMS was not accessed. Furthermore, the mechanisms of perceived motor competence and PA engagement contributing to health trajectories were also not assessed. Duncan, Eyre and Oxford (2017) implemented an INT intervention with five to eight-year-olds over ten weeks, replacing one of two statutory PE lessons (30-40 minutes) per week. The magnitude of FMS process and product performance ability improvement was reported to be significantly greater in the intervention group compared to the control group (Duncan, Eyre and Oxford 2017). Boys in the intervention group demonstrated significantly greater perceived motor competence than those in the control group; however, no difference was observed in girls.

Collectively, Faigenbaum et al. (2011) and Duncan, Eyre and Oxford (2017) show the potential benefit of INT in improving the contributing mechanisms suggested towards positive health trajectories of children (Stodden et al. 2008); although the mechanism of PA was not assessed by either study which may provide further insight into the extent of the benefit INT may have of positive health trajectories. As both interventions were integrated into PE, curriculum aims and developmental expectations should be considered. Participants of both studies were within the learning phase leading to ‘mastery’ of FMS (five-to-seven-year-olds; key stage one). Thus, it can be suggested that during this stage of learning, INT would potentially benefit mastery attainment while FMS are being acquired and developed. Literature is yet to show if INT also influences FMS of children who are expected to have already mastered FMS and are in the transitional phase where they are being applied in sporting contexts (eight to 11 years; key stage two). Furthermore, the long-term effects of the suggested benefits of INT cannot be explored due to the lack of follow-up data. Faigenbaum et al. (2011) and Duncan, Eyre and Oxford (2017) only conducted assessments pre and post-intervention.

2.9 Summary Statement

The majority of children in England are not engaging in sufficient amounts of PA to elicit health benefits. Children are also not able to sufficiently demonstrate skills that are required for them to engage in PA. Lifelong PA and the subsequent health benefits are therefore compromised, with children living in deprivation and those from BAME backgrounds seemingly at greater risk. The prevalence of FMS within these groups where FMS are expected to be acquired during early childhood and mastered during middle childhood is scarce and yet to be established but are potentially critical (*see Study One; section 6.0*). Mechanisms of PMC and HRF are theorised to influence the prevalence levels and relationship between FMS and PA, leading to children being of a health or unhealthy weight status. However, the direct associations between these mechanisms as well as the entire model observing indirect relationships are yet to be observed through experimental data in a deprived and ethnically diverse sample (*see Study Two; section 7.0*). Further understanding of the practical constraints that present as barriers and facilitators to FMS development and PA engagement, experienced by children within these specific groups is also important (*see Study Three; section 8.0*). Utilising both quantitative and qualitative approaches will provide a more detailed picture and greater clarity of the underlying influencers of the low PA engagement levels and the limited evidence of low FMS proficiency levels in early childhood. Once greater clarity is provided, tackling FMS proficiency and PA engagement can be better informed considering the objective scientific research base focused on interventions as well as the practical reality of implementing them specifically to children living in deprived and ethnically diverse areas in England (*see Study Four; section 9.0*).

3.0 THESIS MAP

Table 3.1. Thesis map

STUDY	AIMS	OBJECTIVES
Study 1: *"Fundamental motor skills of children in deprived areas of England: a focus on age, gender and ethnicity."*	To asses FMS mastery of males and females children schooling in deprived ethnically diverse areas in England.	• To examine process and product FMS of males and females in early and middle childhood. • To compare process and product measures of FMS in males and females as well as Black, White and Asian ethnicities between and within children in early and middle childhood.
Study 2: *"The mediating roles of perceived motor competence and health-related fitness for children's physical activity."*	To examine factors affecting motor competency and moderate to vigorous physical activity engagement. Exploring and objective context for study one.	• To examine FMS, MVPA, PMC and HRF during early and middle childhood. • To assess the indirect associations between FMS and MVPA bi-directionally through PMC and HRF during early and middle childhood.
Study 3: *"Barriers and facilitators of FMS development, pa engagement and PE: a primary school teacher's perspective."*	To explore a Teachers perspective of FMS development, PA engagement and PE curriculum in England. To provide additional context of study one and inform study four.	• To identify the perceptions and suggestions of the following topic of teaching staff in schools located in deprived ethnically diverse areas: ○ PA and PE in England ○ Barriers and facilitators of PA and motor development ○ PE within the curriculum and the delivery of PE ○ Training for PE ○ Incorporating PE specialists in the delivery of PE
Study 4: *"The effect of integrative neuro muscular training on fundamental motor skills and health-related fitness in nine-to-ten-year-old"*	To assess the effect of a 6-week INT programmed on FMS and HRF measures in nine-to-ten-year-old males and females at pre-, post and post-six week intervention period.	• To asses FMS and HRF measures at baseline • To implement a 6-week INT programme • To assess FMS and HRF measures immediately post the intervention programme To assess FMS and HRF measures post 6-weeks intervention

4.0 OVERVIEW OF METHODOLOGICAL TOOLS

4.1 Process and Product-oriented Fundamental Movement Skill assessment tools

The method used for assessing FMS varies from study to study, having been carried out through a means of subjective tools and objective measures. Process-oriented measures are "the systematic observation and introspective judgement of the quality of human movement to provide the most appropriate intervention to improve performance" (Knudson and Morris 1997). Whereas product-oriented measures assess the product or outcome in the form of a number or quantity, for example running speed in seconds, horizontal jump distance in centimetres. Both methods present favourable and undesirable attributes (*Table 4.1*), however, FMS assessment tools founded on subjective measures and assessment are primarily used within literature (Logan et al. 2017a). A main beneficial factor of process-oriented measures is that they provide insight into the understanding of performance proficiency, which is not observed through product-oriented measures (Haywood, Roberton and Getchall 2012). Assessors can, therefore, examine components of a skill as well as the overall skill to establish a child's stage of development. This is vital when aiming to implement interventions to improve proficiency but not achievable through product-oriented assessments as there is no way of identifying how a child performs the skill. Despite the inability to assess proficiency, product-oriented measures do play a role in PA participation as the greater a child achieves (performance), the greater the likelihood of continual participation. Furthermore, during competitions in childhood (i.e. sports day) the outcome measure determines results (e.g. how fast a child can run, how far a child can jump). The better a child performs the greater the achievement and how a child performs the skill is not considered in many instances. The means of assessment also need to be taken into account and will be explored in detail later, however; FMS process assessment tools have been validated in children up to the mid-teenage years (*Table 4.4*) at which point they are expected to be competent in skills. Process assessments may, therefore, be redundant beyond this point making product assessments more reliable with norm data spanning across childhood, adolescence and adulthood (Hoffman 2006). Both process and product-oriented assessments have their place in PA engagement during childhood and across the lifespan though when considering prescription of movement assessments are better suited to process assessment and when solely considering objective outcomes product-oriented assessments show a preference.

The use of both assessment methods may vary depending on the aims of the assessor however both process and product-oriented assessments contribute to establishing a child’s FMS development. Process elements relate to how a child conducts the skill and the product element identifying their measure of performance. A lack of clarity and understanding of the relationship between the two methods has been highlighted. Logan and colleagues (Logan et al 2017a) reported variances in statistical significance and strength of correlations between process and product-oriented assessments across age groups (four-to-five-year, seven-to-eight- years and ten-to-11 years), between skills (long jump, hop and throw) and assessment tools (TGMD-2, “Get Skilled Get Active” and Developmental sequences). Therefore, observing one of the two assessment methods individually would not provide a comprehensive understanding of a child’s FMS. In light of these recent findings research aiming to improve proficiency through interventions would benefit from combining the assessment of process and product-oriented measure; enabling the assessment of proficiency development as well as performance through minimal amounts of literature combine this assessment.

Table 4.1. Process and product-oriented FMS assessment comparison.

FMS Measure	Benefit	Limitation
Process-oriented	Identify specific components of movement patterns that are being performed with high or low proficiency. Assessment undertaken in a more comprehensive and contextualised manner. Can be completed in a number of environments providing the appropriate equipment (e.g. video recorder) is present.	Data collection and assessment times are completed separately and are timely. Outcome is not considered. A variety of assessment tools are used within the literature. Norm values for classifications are established based on the children in the country of origin. Assessors require extensive training.
Product-oriented	Can be completed in a short space of time. Capable of being conducted on large groups fairly easy. Assessors can be from a more general background; extensive training of movement competencies is unnecessary.	No explanation of proficiency. Validity is dependent upon the population used to gather normative values.

4.1.1 Process-oriented fundamental movement skill assessment tools

Researchers have produced many different process-oriented assessment tools that vary in purpose with a range of specifications for use and analysis such as gender, age range, number of skills, and checklist format (Cools et al. 2009). Furthermore, there is an inability to compare proficiency classification between tools across all skills (Logan et al.2017a). It is, therefore, a requirement of researchers to critically assess FMS assessment tools (FMS-AT) used to ensure validity and reliability of conduct and results are sound. Furthermore, criteria have been suggested for the selection of FMS assessment tools and more specifically those used in an educational research setting (Barnett and Peters 2004, Cools et al. 2009; *Table 4.2*).

As previously mentioned, the literature identifies many different FMS-AT. Several studies have reviewed and compared the different FMS-AT available in the literature. Regarding previous literature of a similar nature (Wiart and Darrah 2001, Barnett and Peters 2004, Tieman, Palisano and Sutlive 2005, Yoon, Scott and Hill 2006), Cools et al. (2009) is the most up-to-date systematic review, encompassing the greatest number of assessment tools observed (*Table 4.3*); many of which were also included in previous reviews. Cools et al. (2009) aimed to explore the usefulness, assessing motor skill capacity in the context of educational research.

Table 4.2. FMS assessment tool selection identification criteria. Adapted from Barnett and Peters (2004) and Cools et al. (2009).

Number	Criteria
1	Purpose of assessment and purpose of the test
2	Nature and range of the items included in the tool
3	Nature in which performance is measured
4	Age specificity and appropriateness of test
5	Simplicity of the test
6	Cultural similarity between norm and test group.
7	Proportion of test items in relation to time allocated for testing.

Table 4.3. FMS assessment tool journal inclusion

Literature	Motoriktest für vier- bis sechsjährige Kinder (**MOT 4-6**).	Movement Assessment Battery for Children (Movement-ABC – **Movement ABC-2**)	Peabody Developmental Motor Scales-Second Edition (**PDMS-2**)	Körperkoordinationtest für Kinder (**KTK**)	Test of Gross Motor Development, (TGMD, **TGMD-2**)	Maastrichtse Motoriek Test (**MMT**)	Bruininks-Oserety Test of Motor Proficiency (**BOTMP-BOT-2**)
	Assessment tools						
Wiart and darrah (2001)		✓	✓		✓		✓
Barnett and peter (2004)		✓	✓		✓		✓
Tieman *et al.* (2005)			✓				
Yoon *et al.* (2006)		✓					✓
Cools *et al.* (2008)	✓	✓	✓	✓	✓	✓	✓

Table 4.4. Fundamental Movement Skill Assessment: administrative aspects. Adapted from Cools et al. (2008).

Test	Purpose	Criteria type	Population demographic origin.	Age specification (years)	No. Of items/ assessment time (min)	Classification of movement	Reference
Motoriktest für vier- bis sechsjährige kinder (mot 4-6).	Assessment of motor developmental status (pre-school)	Product-oriented (three-point rating scale)	Germany	4-6	18 15-20	Locomotion, stability, objects control and fine movement skills.	Zimmer and Volkamer 1987
Movement assessment battery for children (movement-abc – movement abc-2)	Motor impurities in daily life: identification and description.	Product-oriented (six-point rating scale)	USA	MABC: 4-12 MABC-2: 3-16 (3-6, 7-10, 11-16)	MABC (2): 32 (4 age bands; 8 movement patterns per band) 20-30	Manual dexterity skills, ball skills and balance skills.	Henderson and Sugden 1992, Henderson, Sugden and Barnett 2007
Peabody developmental motor scales- second edition (pdms-2)	Motor development assessment and programming for young children with disabilities	Process-oriented (three-point rating scale)	USA	0-7	249 LV: 45-60 STV:20-30	Gross movement subsets: reflexes (8), stationary performances (30), locomotion (89), and object manipulation (24). Fine movement subsets: grasping (26) and visual-motor integration (72).	Foli and Fewell 1983, Folio and Fewell 2000
Körperkoordinationtest für kinder (ktk)		Product-oriented	German	5-14	4	Balance	Kiphard and Shilling 1974,

	Assessment of gross motor skill: dynamic balance				20		Kiphard and Schilling 2007
Test of gross motor development, second edition (tgmd-2)	Identify significant deficit in gross motor performance in children when compared to their peers. To plan programs for children exhibiting delays along with assessing progress.	Product and Process-oriented (two-point scoring system)	USA	3-10	12 15-20	Locomotion: running, galloping, hopping, sliding, leaping, horizontal jumping. Object control: striking a stationary ball, stationary dribble, catch, kick, overhand throw, and underhand roll	Ulrich 1985, Ulrich 2000
Maastrichtse motoriek test (mmt)	Objectify qualitative and quantitative aspects of movement.	Process-oriented (three-point rating scale)	The Netherlands	5-6	LV: 70 (34 quantitative, 36 qualitative) SV: 20 LV: 30 SV: 7	Static balance (standing); straight, arms out in pronation and one leg Dynamic balance: walking on heels, tiptoe, hopping on one leg, hopping in a straight line Ball skills: catching, bouncing Manual Dexterity: diadokinesia, finger-thumb opposition, foot	Vles *et al.* 2004

						tapping and tracing pencil between lines	
Bruininks-oserety test of motor proficiency (botmp-bot-2)	Identification of deficits in individual with light to moderate motor coordination problems.	Process-Oriented Dependent upon individual items; 2 to 13-point scoring system	USA	4-21	LF: 53 SF: 14 LF: 45 - 60 SF: 15 - 20	Bilateral coordination, balance, running speed and agility, upper-limb coordination, strength	Bruininks 1978, Bruininks 2005

NR: NOT REPORTED, LV: LONG VERSION, SV: SHORT VERSION, LF: LONG FORM, SF SHORT FORM

All seven FMS-AT’s were deemed appropriate for their intended purpose (Cools et al. 2009). However, with a focus on acquisition, development of FMS over time across different ages and mastery, not all tools are suitable. From as early as 1980 basic motor skill acquirement has been observed to occur before 5-6 years (DeOreo and Keogh 1980), with a vast majority of development and improvement of mastery being achieved during the ages of four-to-ten-years-old (Booth et al. 1997); the influence of age is presented throughout literature with older children exhibiting greater mastery than younger children (Haywood and Getchell 2014). Therefore with guidance from the FMS tool selection identification criteria (Barnett and Peters 2004, Cools et al. 2009; *Table 4.2*), due to the age limitation; not encompassing the latter stages of FMS development; the use of the assessment tools MOT 4-6, PDMS-2, MMT and BOTMP-BOT-2 (*Table 4.4*) are identified as inappropriate for the use of observing the development of FMS over time. Furthermore, although the KTK assessment tool age specification indicates ages five-to-14-years only one gross motor skill (dynamic balance) is observed and is therefore insufficient for observing a range of FMS in children; preventing a global observation of ability. Therefore, with regards to the selection identification criteria, the MABC-2 and TGMD-2 seem most appropriate for further critique (*Table 4.5*).

TGMD-2 and MABC-2 reliability and Validity

Identifying the reliability and validity of an assessment tool is pivotal before use as results of the test must be well-founded, stable and consistent with minimal error variance. Ulrich (2000) provides reliability and validity data direct from the normative sample enabling for critique. The MABC-2 will be appraised through the author’s test manual (Henderson, Sugden and Barnett 2007) and a review and critique of literature focusing on the MABC-2 (Brown and Lalor 2009) to enable greater depth of critique.

Table 4.5. FMS assessment tool selection justification (Ulrich 2000, Barnett et al. 2004, Henderson et al 2007, Cools et al. 2009

Selection Criteria	Assessment Tools		
	TGMD-2	MABC-2	
Purpose of assessment and purpose of the test	Identify significant deficit in gross motor performance in children when compared to their peers. To plan programs for children exhibiting delays along with assessing progress.	Identification, intervention planning, program evaluation and as a research tool.	
Nature and range of the items included in the tool	12	32	
Nature in which performance is measured	Product and Process-oriented	Product- Oriented (six-point scale)	
Age (years) specificity and appropriateness of test	3-10	3-16 (Band 1: 3-6, Band 2: 7-10, Band 3: 11-16)	
Simplicity of the test: movement patterns assessed	Locomotor: run, gallop, hop, leap, horizontal jump, slide. Object Control: Striking a stationary ball, stationary dribble, kick, catch, overhand throw, and underhand roll.	Band 1	Manual dexterity: post coins, threading beads, trail Aiming and catching skills: catching a bean bag, throwing a bean bag onto a mat Balance skills: one-leg balance, walking heels raised, jumping on mats
		Band 2	Manual dexterity: placing pegs, threading lace, drawing trail 2 Aiming and catching skills: Catching with two hands, throwing bean bag onto matt Balance skills: One-Broad balance, Walking Heel-to-Toe forwards, Hopping on matts
		Band 3	Manual dexterity: Turning pegs, Triangle with nuts and bolts, drawing task 3 Aiming and catching skills: catching with one hand, throwing ball at a wall mounted target Balance skills: two-board balance, walking toe-to-heel backwards, Zig-zag hopping
Cultural similarity between norm and test group.	Normative data based on 1,208 children in the USA. Inconsistency in cultural comparisons.	Standardized by 1,172 UK children from varied demographics.	
Proportion of test items in relation to time allocated for testing.	15-20 min	20-40 min	

Reliability

Reliability of the TGMD-2 and the MABC-2 have been assessed in varying capacities across content sampling, time sampling and inter-rater reliability (IRR). Content sampling was observed across the eight age intervals (three-to-ten-years) firstly through standard errors of measurement showing uniformly low scores (four-to-five) indicating a high degree of test reliability (Ulrich 2000). High coefficient alphas were observed across age, gender and ethnic background, ranging from 0.91 to 0.97, further identifying the strength of reliability held within the TGMD-2 in the area of content sampling (Ulrich 2000). Content sampling lacked exploration in the MABC-2 (Henderson, Sugden and Barnett 2007, Brown and Lalor 2009). It should be noted that literature presents equivocal results of this reliability of the normative data in children on different continents to that of the normative population (Cepicka et al. 2010, Valentini 2012, Farrokhi et al. 2014). Thus, it may be of more benefit to utilise raw data scores as opposed to classifications based on norm values within child populations outside of America.

When considering time sampling the TGMD-2 exhibited sufficient coefficients across the normative sample (three-to-ten-years-old; *n*=75) indicating stability over time (Total sample: locomotor r=0.88, Object control subtest r= 0.93 and Gross motor quotient r=0.96) (Ulrich 2000). The MABC-2 was suggested to have reasonable test-retest reliability (TRR) (Brown and Lalor 2009) within individual elements (manual dexterity r= 0.77, aiming and catching r=0.84, and balance r=0.73) (Henderson, Sugden and Barnett 2007) as well as total test score (r=0.80). Both FMSA-T, therefore, shows an acceptable level of time sampling although the MABC-2 total test score is slightly less than the TGMD-2 (r=0.80 vs r=0.96). In addition to this, the protocol carried out by Ulrich (2000) (30 completed protocols twice) to assess time sampling does not complement recommendations for observing stability over time (Simons et al. 2003) and it is unclear if the MABC-2 upholds the recommendation due to a lack of description of methods by Henderson, Sugden and Barnett (2007) and, Brown and Lalor (2009). Due to the differences in components assessed within each FMSA-T as well as TGMD-2 utilising coefficients and the MABC-2 utilising TRR, direct comparisons between time sampling should be carried out with caution.

Finally, the inter-rater reliability of the TGMD-2 was assessed independently by 2 staff members from PRO-ED's research department (Ulrich 2000). Thirty completed protocols from the normative sample were included (Ulrich 2000). Both subtests (locomotor and object control) and the gross motor quotient received an error score of 0.98 (Ulrich 2000). It can, therefore, be accepted that the TGMD-2 holds sufficient inter-class correlations. Correlations for the MABC-2 were assessed in relation to inter and intra-class correlations, ranging from 0.79 to 0.92 and 0.79 to 1.00, respectively (Chow, Henderson and Barnett 2002, Faber and Nijhuis van der Sanden 2004, Brown and Lalor 2009). Intra-rater reliability was not observed by Ulrich (2000) however, inter-rater reliability of the TGMD-2 was greater than the MABC-2 observed for the MABC-2 (Faber and Nijhuis van der Sanden 2004). It should be noted that participants through whom these observations of reliability were concluded were those of Band 3 (11–to-16-years; *Table 4.5*) and therefore cannot be generalised across the age bands. Moreover, Chow et al. (2002) used an experimental version of the MABC-2 where instructions and scoring criteria were translated into Chinese while Faber and Nijhuis van der Sanden (2004) literature was sourced from an unpublished manuscript; no peer review. It is therefore inappropriate to deem the MABC-2 as reliable based on these measures. The TGMD-2 exhibits a greater and more stable inter-rater reliability than the MABC-2 when assessing the acquisition and development of FMS in young children. This is particularly important when observing children overtime during primary school years; in the majority of primary schools, each class will have a different teacher every year. The TGMD-2, therefore, would provide more reliable results, potentially reducing the influence different assessors may have.

Validity

The validity of both FMSA-T's has been observed through content, construct and criterion-related validity measures. Content validity was established within the TGMD-2 by three content-experts (Ulrich 2000) and an 'expert panel' was used for the MABC-2 (Brown and Lalor 2009). Due to the lack of methods identified for the MABC-2 the ability to appraise the MABC-2 content validity is withdrawn.

The TGMD-2 construct validity was identified through the correlation of item performance and test total score (Guildford and Fruchter 1978) cited by Ulrich 2000) showing coefficients of median discriminating powers indicating sufficient construct validity. Values identified in each of the eight age intervals range between 0.39 – 0.58 for locomotor and 0.39 – 0.48 for object control. Much of the literature does not present the direct assessment of construct validity for the MABC-2 (Henderson, Sugden and Barnett 2007, Cools et al. 2008, Brown and Lalor 2009). However, Brown and Lalor (2009) highlighted a method in the MABC-2 test manual reflective of Guilford and Fruchter (1978) method for observing construct validity used by Ulrich (2000). Correlations between individual sections and total test standard scores ranged between 0.26 and 0.76. The construct validity varies within both FMSA-T, with one not overtly greater than the other although the method used within TGMD-2 was conducted within individual age groups, providing greater scope compared to the MABC-2.

Criterion-prediction validity was established by Ulrich (2000) through the Basic Motor Generalizations subset of the Comprehensive Scales of Student Abilities (CASSA; Hammill et al. 1994). Partial correlations where age was controlled for between the TGMD-2 and CSSA were 0.63 for composite, 0.41 for Object control and 0.63 for Locomotor. The TGMD-2, therefore, has a valid criterion-prediction with moderate-strong correlations. In contrast, Brown and Lalor (2009) provided insufficient evidence of the MABC-2 criterion-related validity as a result of the limitations of evidence provided by Henderson et al. (2007); type of criterion validity, small sample sizes, use of individual test-sections, out of date items within sections, no control groups and use of unpublished manuscripts (Kavazi 2006, Siaperas et al. 2006, Henderson, Sugden and Barnett 2007). Subsequently, the TGMD-2 presents greater criterion-related validity than the MABC-2.

To assess FMS acquisition and development in children the TGMD-2 and MABC-2 are deemed most appropriate of current literature; both tools identify observations of FMS acquisition and development with the intent to implement an intervention. The appraisal and comparison of the reliability and validity of the TGMD-2 and MABC-2 is challenged by the lack of literature of the MABC-2 tool. However, it can be accepted that the TGMD-2 presents greater reliability and validity. It provides an accurate measure for assessing development at any one time and the comparison of FMS over time. Subsequently, it is appropriate to accept the TGMD-2 as the more suitable tool in assessing the acquisition and development of FMS during childhood.

4.2 Measures of physical activity in Children

The assessment of PA has been conducted using subjective and objective measures in field-based research (Sirard and Pate 2001). Subjective measures of PA enable assessments of large population groups in a cost-effective manner that can provide specific details regarding PA. The validity of these is questionable in children due to the sporadic nature of PA typically engaged in by children as well as their limited cognitive ability to recall information accurately (Sirard and Pate 2001, Sylvia *et al.* 2014). Objective tools are the most reliable, valid and used field-based 8tools which overcome the issues with using subjective measures in a child population.

Table 4.6. Overview of advantages and disadvantages of PA assessment methods. (Adapted from Sirard and Pate 2001, Vanhees et al. 2005, Hills et al. 2014, Sylvia et al. 2014).

	Method	Advantages	Disadvantages
Criterion methods	**Direct behavioural observation**	Provide contextual information: PA is influenced by the environment and information regarding this will is extremely important for cognition and changing sedentary behaviour.	Time consuming. Potential reactivity of study participant. Limited in monitoring time. Subjectivity of the observer.
	Doubly labelled water (DLW)	Accurate and valid measurement of energy expenditure; metabolic processes are measured. Applicable for children and adults. Induces no change in PA behaviour in daily free-living conditions.	Expensive and not appropriate for large-scale studies. Analysis requires expertise. No indication of specific activities, only total (daily) energy expenditure. At least recordings over 3 days.
	Indirect Calorimetry	Accurate and valid measurement of short-term energy expenditure.	Expensive. Limited to laboratory sitting until better portable devices become available.

Objective methods			Indirect measure of PA.
	Direct Observation	Environmental aspects considered (e.g. location) Specific activities determined Presence of others considered	Time and energy burden of researcher Ethical approval Energy expenditure difficult to determine
	Heart rate monitoring	Lightweight and portable. Directly related to physiological responses to a PA. Detailed data recording over extended period. Possibility of measuring more specific activity.	Measurement of energy expenditure in response to PA, not actual PA. Not suitable for very low-intensity PA as heart rate is affected by non-activity related environmental factors. Individual calibration of heart rate – PA relationship required Psychological and environmental stress in addition to stress and medication may also impact heart rate.

Pedometers	Lightweight and portable Easy to use. Inexpensive. Non-reactive Free living conditions	Only walking or running steps monitored but not distinguished between; no recording of horizontal or upper-body movements. Lack of data storage. Limited validity for energy expenditure estimations. No information of specific activity, only total (daily) PA.
Accelerometers	Lightweight and portable Easy to use. Non-reactive; represent free living behaviour. Uni-axle and for extended period of time. Indication of intensity of the movement (possibly measuring a specific activity).	Limited validity for energy expenditure estimations. Limited in their ability to assess cycling, locomotion on a gradient or other activities with limited torso movement. Unable to detect increased metabolic work associated with walking on soft surfaces, carrying or pushing objects.

Subjective methods	**Self-report**	Can be conducted in large populations at relatively low cost Easily distributed. Low investigator and respondent burden. Can be adapted to meet population.	Recall errors Deliberate misrepresentation Social desirability, particularly in children Social and cultural differences in interpretation
	Interviews	Can be conducted in large populations at relatively low cost. Can be adapted to meet population.	See ‘Self-Report’ Time for analysis
	Proxy-Report	Can be conducted in large populations at relatively low cost. Reduce errors resulting from a child’s limited cognitive ability.	Assessment of subjective behaviour Bias from perception of participant (social, cultural, professional)
	Diary	Low cost Easily distributed Can be adapted to meet population.	Participant burden to comply with engagement.

4.2.1 Objective Measures of physical activity

Objective measures of PA provide assessments that are recommended where criterion methods cannot be conducted (Sirard and Pate 2001). Methods of objective assessment vary from study to study, though as previously mentioned there is a limitation to subjectivity. Thus providing greater accuracy and reliability of results, and reducing the likelihood of bias within the data (Hills et al. 2014, Sylvia et al. 2014). Within literature, lightweight and portable devices such as pedometers, heart rate monitors and accelerometers have all been used to assess the PA engagement levels of children.

4.2.2 Pedometers

Pedometers measure the volume of steps taken over time (Sirard and Pate 2001, Sylvia et al. 2014). Typically, this is conducted by a spring mechanism in the device which is activated as a result of the foot impacting the ground and a vertical acceleration of the hip occurs (Sirard and Pate 2001, Sylvia et al. 2014). Only bodily movement is accounted for (Sirard and Pate 2001, Sylvia et al. 2014). The devices are valid and reliable for measuring activity accounts in children as well as being relatively cheap and easy to use (McNamara, Hudson and Taylor 2010). However, due to the spring mechanism, pedometers only assess the movement of the hip. Observations of PA are therefore limited to walking and running movements (Sirard and Pate 2001, Sylvia et al. 2014). Furthermore, pedometers are incapable of assessing the intensity of the exercise being engaged in (McNamara, Hudson and Taylor 2010). Where the UK recommended guidelines prescribe specific intensities and types of PA for children (*see section 2.3.1*), pedometers are therefore limited in their ability to provide sufficient experimental data for these.

4.2.3 Heart rate monitors

Heart rate (HR) monitors track physiological responses of the heart in real-time indicating PA frequency, duration and intensity levels as well as energy expenditure (Sirard and Pate 2001, Sylvia et al. 2014). Therefore, more specific data is provided by HR monitors than pedometers although they are more costly. The devices can be worn by children around the chest and the wrist providing a detailed analysis over time and have been validated in adults and child populations (Freedson and Miller 2000). Caution when using HR monitors has been highlighted as HR responses are not exclusive to bodily movement. Physiological and environmental stress factors can influence physiological responses as well as factors of caffeine and medication (Sirard and Pate 2001). Furthermore, HR is a physiological response; movement occurs and the heart responds to meet the necessary physiological demands. An initial delay, as well as a delay in the latter end of the hearts response to PA (e.g. high HR levels are sustained when activity has stopped), therefore occurs. Where PA intensities are very high or low, monitoring HR is weakly correlated (Welk, Corbin and Dale 2000). This is suggested to be due to the lack of a linear relationship between HR and energy expenditure (Sylvia et al. 2014), considering the factors influencing HR aside from bodily movement previously discussed. More specifically to children, due to the differences in HR depending on the proportion of musculature utilise, sex, age, body size (i.e. overall mass, lean mass, fat %), and training status it is hard to compare HR as an outcome measure (Freedson and Miller 2000). Furthermore, considering the lag in HR previously discussed and the sporadic nature of PA engagement exhibited in children HR output may be masked and therefore present inaccurate data (Trost 2001).

4.2.4 Accelerometers

Accelerometers contain piezoelectrical transducers that detect forces of acceleration in multiple movement planes (Sirard and Pate 2001, Hills, Mokhtar and Byrne 2014, Sylvia et al. 2014). Several devices with slightly unique features are available and used within the literature (Trost, Mciver and Pate 2005). Outputs of accelerometers are highlight dependent upon the model used and device positioning which will be explored in detail later (*see section 4.2.4.1* and *section* 4.2.4.2.). Much like HR monitors and pedometers, accelerometers are unable to record/categorise specific movement patterns/activities (e.g. throwing, catching, skipping, and leaping) during the period of assessment. While this limitation is present, participants of all ages can use the devices. There is also greater sophistication of the mechanism within the device, compared to the pedometer, which contributes to the greater expense of the device however it provides a greater assessment of movement in multiple planes. This also provides the ability to present data relating to PA frequency, intensity and duration as does an HR monitor but without the influence of physiological responses such as anxiety providing more accurate outputs. The lag previously discussed influencing HR monitor outputs is also not present in accelerometers, enabling the devices to provide data in real-time.

Considering the advantages and limitations discussed (*see Table 4.6*) when collecting PA data in a large sample of children with the need to identify PA frequency, duration and intensity across specific time points across multiple days, accelerometers are most appropriate. While using accelerometers some elements need to be considered to ensure the practice is of a high standard. These include the model of the accelerometer used, where the monitor will be positioned and an appropriate time for the monitor to be worn and cut-points utilised for data analysis.

4.2.4.1 Accelerometer model

Several different models of accelerometers have been used in the observation of PA (Ott *et al.* 2000, Puya *et al.* 2004, Trost, Mciver and Pate 2005). Uniaxial (vertical) and multiple axis (bidirectional, triaxial, omnidirectional) devices have exhibited comparable strong positive correlations between outputs (Trost, Mciver and Pate 2005). The strength of the strong positive correlations varied between models thus, some may be more favourable than others. For example in children, in comparison to the ActiGraph, the TriTrac-R3D presented a stronger positive correlation with scaled oxygen consumption (r=0.91 and 0.78 respectively; Eston *et al.* 1998). However, the advancement and technology used within more recent research deemed the ActiGraph is the most commonly used accelerometer and has the greatest body of evidence in support of its use (de Vries *et al.* 2006).

The GT1M model and its updated counterparts GT3X and GT3X+ comparable; when worn around the waist by children and adolescents aged 7-18 years in lab-based activities (Robust and Trost 2012). Intraclass correlation coefficients exceeded the 95% CI for total vertical axis counts, vector magnitude counts and MVPA estimations; (95% CI = 0.989–0.996), 0.981 (95% CI= 0.969–0.989), and

0.996 (95% CI= 0.989–0.998), respectively (Robust and Trost 2012). Vanhelst *et al.* (2012), further supported Robust and Trost (2012); GT1M and GT3X were found to be comparable in free-living conditions in adults. Contrary to this, Hänggi, Philips and Rowlands (2013) disputed the ability for researchers to interchange between GT1M or GT3X models in children. Significant discrepancies in vertical and antero-posterior vectors were found in some activities. The GT1M exhibited significantly greater vertical mean counts in Nintendo Wii boxing, slow running and medium running (p >0.001; Hänggi, Philips and Rowlands 2013). The GT3X exhibited significantly greater antero-posterior mean counts in the same activities as well as slow and brisk walking (p >0.001); although, as Robust and Trost (2012), Hänggi, Philips and Rowlands (2013) findings indicated that intensity classifications were comparable between the two models. Based on literary findings, it can be concluded that it is acceptable to compare and use a range of ActiGraph models within research regarding exercise intensity classification. Caution should be taken however when using and collecting/comparing data from different models on factors such as step and count output. As such, the ActiGrap model wGT3X-BT was used within the current research. It should be noted that both Robust and Trost (2012) and Hänggi, Philips and Rowlands (2013) conducted similar protocols for their studies; laboratory setting with the child population. The positioning of the monitor, however, differed in both studies. Robust and Trost (2012) positioned the monitor around the waist of participants while Hänggi, Philips and Rowlands (2013) participants wore the monitor on their hip. This leads to the next factor of consideration, positioning.

4.2.4.2 Accelerometer positioning

Accelerometer positioning has been highlighted as a cause for variability in outputs (Westerterp et al. 1999) in children (seven-to-11-years) populations (Hildebrand et al. 2014). Accelerometers ActiGraph GT3X+ and GENEActiv both exhibited significantly greater outputs when worn on the wrist than on the hip (p < 0.001) but comparable outputs when positioned in the same location in adults (Hildebrand et al. 2014). Contrary to this, children exhibited variations in outputs when considering brand and placement of the device (Hildebrand et al. 2014). Therefore, it was deemed that the use of different brands and positioning in studies inhibits absolute comparability of PA engagement of the child population within literature (Hildebrand et al. 2014). Matthews et al. (2012) recommended that researchers consider the following when selecting placement sites: (a) desired characteristics of PA to be monitored; (b) populations used, how and where to attach the monitor with regards to ethics and practicality. Accelerometers present specific positioning limitations with regards to practicality and compliance. For example, Nyberg et al. 2009) found participants had higher compliance with wrist-worn accelerometers than those worn on the hip. While being worn on the wrist the devices were rarely removed which was speculated to be due to reduced likelihood of obstruction (e.g. while sleeping, getting dressed, and engaging PA; Nyberg et al. 2009). If the device is removed less, there is less opportunity for children to forget to wear the device again (Nyberg et al. 2009). Furthermore, with greater compliance comes greater potential for useable data, thus making it more practical for devices to be worn on the wrist, particularly as children already present a lower level of compliance than adults (Hildebrand et al. 2014). Other aspects have also been highlighted throughout literature such as loss of collection accuracy with hip worn monitors, for example, the lack of PA registered in upper body activity (Troiano et al. 2008). Therefore, when assessing the PA engagement of the child population, it would be more desirable for accelerometers to be placed on the wrist. Enabling the potential for compliance to be increased and subsequently the volume of potential data collected.

4.2.4.3 Accelerometer wear time

While using accelerometers, the wear time for participants is a common area of discussion. Many different numbers of days, hours within each day and days of the week (weekdays vs. weekend days) have been proposed (Barreira *et al.* 2015*)*. Reliability of data increases with a greater number of minimum days and hours worn within each day (Hinkley et al. 2012, Rich et al. 2013). It should also be considered that increasing reliability in this way may reduce compliance. Rich et al. (2013) has suggested that devices can be worn from as little as ≥2 days (≥10 hours) in the child population to achieve good-excellent reliability (*r* =0.86; Rich et al. 2013). Conversely, Hinkley et al. (2012) proposed that for data to reach a medium (good/acceptable) reliability (*r*= 0.7), 2.7-2.8 wear days must be achieved with ≥10 hours within each day. To achieve medium reliability over 3.3-3.4 days, 7 hours wear time per day must have been completed (Hinkley et al. 2012). For data to achieve a reliability of 0.8, 4.6-9.3 days were required for wear time and excellent reliability (r=0.9) 10.3 – 21.0 days were necessary for wear time (Hinkley et al. 2012).

As seen in literature even with acceptable levels of reliability total number of suggested wear days varies from study to study. An earlier review of literature by Trost et al. (2005) suggested 7 days is most appropriate. Literature based on child and adolescent populations present a variation of 5 days (4 – 9 days) to achieve 0.80 in reliability; thus presenting an appropriate rationale for Trost et al. (2005) suggestions of device wear time duration. It is therefore understandable that wear time is most commonly validated at 4 days with a minimum of ≥10 hours per day (Cain et al. 2013). Furthermore, a day for familiarisation was suggested in the literature by Van Cauwenberghe et al. (2011). During the first day, there is the potential for children to be excited and adapt their PA behaviours (e.g. shaking their wrists). Therefore, it would be beneficial to add a day to the suggested 4 days to account for this. In addition, Van Cauwenberghe et al. (2011) highlighted the need for a removal day; further adding an additional day as removal may occur at random timings depending upon the schedule of the schools; subsequently, amounting to a total of 6 wear days.

Within the total wear days, literature presents a debate on the use of week and weekend days. Rich et al (2013) concluded comparability of assessing data including and independent of weekend days. Even though it was reported in the study that reliability slightly increased (e.g. r = 82 vs. 88) when using children with weekend data in comparison to those with only weekday data. Contrarily, Hinkley et al. (2012) reported that both weekday and weekend days must be included in the analysis to enable researchers to asses true habitual PA. Weekday and weekend days were shown by Hinkley et al. (2012), with participants from Australia engaging in significantly more PA on the weekend than on weekdays. This was exhibited in all data, irrespective of the minimum number of hours used in assessment (t = 12.49–16.76, p< 0.001 for all). Nyberg et al. (2009) is in support of the necessity to include both week and weekend day but opposed to reports by Hinkley et al. (2012). Nyberg et al. (2009) described six-to-ten-year-olds from Stockholm to participate in significantly less weekend PA in comparison to weekdays across all age groups (individual years) where gender was separated (girls 782 (6.7) vs 681 (7.7) counts per min $p < 0.001$; boys 853 (7.1) vs 729 (8.0) counts per minute $p < 0.001$). Moreover, the reduced PA engagement on weekends was also exhibited across participants of different levels of engagement (low, medium and high). The difference prevalence of PA engagement (weekday vs. weekend) may further be explained in part by the facilitative school environment, which will be explained in further depth later, as well as from cultural differences in PA across countries (Bardid et al. 2015) (Austria; Hinkley et al. 2012 vs. Stockholm; Nyberg et al. 2009).

Despite the variation in results, the significant difference in PA engagement during weekdays and weekends is evident. Unless purely weekend PA data is being assessed, it is not acceptable to assess weekday or weekend data independently, as Rich et al. (2013), to represent PA activity as a whole; even though results were shown to be comparable (Rich et al. 2013).

4.2.4.4 Accelerometer cut-points

Accelerometer cut-points have been widely assessed across all age groups from child to adulthood to classify the intensity of physical activity (Migueles et al. 2017). Within the literature base exploring the child population, the vast majority of the cut points have been established using hip positioned monitors (Migueles et al. 2017). Although cut-points established on the hip are valid, reliable and regularly used to inform studies, as previously discussed (*see section 2.4.2.2*), monitors are better suited to being placed on the wrist in child populations. This is due to greater practicality and compliance than hip worn monitors (Nyber et al. 2009). Furthermore, where comparisons have been made between activity intensity established in the hip and the wrist, outputs often differ. Subsequently, there is a consensus that PA intensity should be determined by cut-points established where the monitor was located in the same position (Migueles et al. 2017). Within the child population, although wrist-worn cut-points are fewer than hip-worn cut-points, they would be deemed a more appropriate way to identify the level of PA intensity in children.

A literature review conducted by Migueles et al. (2017) identified a total of three studies establishing wrist-worn cut-points in children and adolescence; one being established in early childhood (Johansson et al. *2015*) and two in middle-late childhood (8-12-year-olds; Chandler et al. 2015 and 10 – 14-year-olds; Crouter et al. 2015). Cut-points from all three studies were determined across 5s Epochs compared to 60s often seen in studies with adult populations, which considers the sporadic nature of PA engagement during childhood (Sirard et al. 2001 and Sylvia et al. 2014). Johansson et al. (2015) provided vector magnitude cut-points for sedentary (≤221), low (222-729) and high (≥730) intensity PA; showing significant differences between all three categories of intensity ($p<0.05$). The cut-points also presented sensitivity and specificity ranging from 60 to 100% and 60 to 92.3%, respectively as well as the area under the curve (AUC; 95% CI) ranging from an average of 0.878 to 0.980; presenting results between 'good' to 'excellent'. It should be considered that due to the sensitivity and specificity shown, time spent in sedentary PA may be overestimated due to higher intensity activities' occasionally being incorrectly classified. However, taking into account significant values, the level of sensitivity and specificity identified and AUC values; cut-points of wrist-worn monitors established by Johansson et al. (2015) are suitable for use when assessing PA engagement during early childhood. Both Chandler et al. (2015) and Crouter et al. (2015) identified valid vector magnitude cut-points. It should be noted that light PA cut-points were not presented by Crouter et al. (2015), even though sedentary values are ≤275 and moderate values range from 416 to 777. Irrespective of this, cut-points validated by Crouter et al. (2015) incurred AUC values ranging from 'good' to 'excellent' (0.83 to 0.94) whereas Chandler et al. (2015) values showed levels that were between 'poor' to 'fair' (0.64 and 0.89). Crouter et al. (2015) also observed non-significant differences when comparing accelerometer data with a gold standard test (indirect calorimetry; mean bias 2.2 to 8.4%) in a regression analysis, thus strengthening the validation of the cut-points. However, it should be considered that large errors were found, with the 95% prediction intervals in the vector magnitude data ranging from -2.55 to 2.96.

Observing PA engagement levels using wrist-worn monitors in the child population is more practically viable in comparison to hip/waist-worn monitors. Although scarce, the current literature providing cut-points to determine intensities of PA, where monitors are placed on the wrist, have been validated against the gold standard of measurement. Though further exploration of the currently established wrist-worn cut-points will broaden the scope of the literature, it is more suitable to observe PA intensities during early and middle to late childhood using cut-points established by Johansson et al. (2015) and Crouter et al. (2015), respectively.

5.0 GENERAL METHODS

5.1 Research ethics and consent

Prior to the commencing of each study, ethical approval was obtained by Coventry University Research Ethics committee (Study one and two: P36658, Study three: P45655, Study four: P47062). Approval was gained by Head Teachers and relevant staff (PE coordinators and class teachers) to gain access to children for recruitment. The parent/guardian of each participant of participants under the age of 18 provided informed consent and participants provided assent. Both parents/guardians and participants were informed of the voluntary nature of participation in each study, and that withdrawal could occur at any time before 2 weeks-post data collection.

5.2 Sampling/recruitment strategy and participants

To ensure that participants were appropriate for the study the most deprived wards in Coventry were identified and schools within these wards were then approached and recruited began where permission was granted.

5.2.1 Ward and school sampling

The Local Concentration measure is used to rank local authorities in 'relation to deprivation levels experienced by the most deprived 10% of the local population' (Insight 2015a). As a result of this measure, Coventry is ranked as the 38th out of 326 most deprived local authority in England (Insight 2015a). An estimated 29% of the child population in Coventry live in Poverty (Coventry City Council 2014). Within Coventry, the wards of, St. Michael's, Foleshill, Henley and, Binley and Willenhall contain the highest percentages of children living in poverty; 47%, 45%, 34%, 32% respectively (Insight 2015a, 2015b) (Coventry Partnership 2010, Coventry Partnership 2012). Thus schools within these wards were approached to participate in all studies through convenience sampling as SES has been found to influence FMS performance ability and PA engagement levels in children (Morley et al. 2015).

The child population of Coventry includes residents from a variety of ethnic groups; 40% of 0 – 15-year-olds are from Black, Asian and Minority Ethnic

(BAME) backgrounds (Insight 2015b). The wards of Foleshill and St. Michael's presents the greatest proportion of ethnic diversity among 0-15-year-olds; 80% and 72% respectively (Insight 2015b). More specifically with the highest concentrations of BAME children living in particular areas within these wards: Courtaulds Edgwick (80.2%), Foleshill South Paradise (72.8%), Hillfields (70.2%), and Upper Foleshill (52.7%; Coventry Partnership 2010). The wards of Henley and, Binley and Willenhall however, have BAME populations aged 0-15-year-olds of 38% (8th highest) and 29% (11th highest) respectively out of a total of 18 wards (Insight 2015b). Convenience sampling was used to select schools within the wards of Foleshill, St. Michael's, Henley and, Binley and Willenhall.

5.2.2 Study information delivery to participants

Prior to the commencing studies one, two and four, a session was arranged with class teachers and the principal investigator to provide them with an overview of the study and organise information delivery dates. An active session including a PowerPoint presentation, including aims and objective of the study, what they would be doing during their PE lessons, advantages and disadvantages of participating, a brief explanation of data analysis and the voluntary nature of the study was stressed. Demonstrations were given and activities were engaged in, reflective of the studies conduct. All information sessions were delivered at an age-appropriate level while also considering space and time available.

5.3 Anthropometric measures

Participants removed shoes and socks during the assessment sessions of studies one, two and three when anthropometric measures were being collected. Standing height and seated height (cm; to the nearest mm) were measured using a stadiometer (Seca 213, Hamburg, Germany). While standing, participants placed feet slightly apart with heels against the board, back straight with cervical spine in a neutral position and eyes facing directly ahead of them (National Institute for Health Research Southampton Biomedical Research Centre 2015b). While seated, participants sat with legs together extended directly in front of them, with their lumbar spine as close to the board as possible, back straight with cervical spine in a neutral position and eyes facing directly ahead of them. Waist circumference was measured while participants were standing using an anthropometric tape measure (HaB direct, Southam, UK). The measurement was taken from the mid-point between the tenth rib and the iliac crest to the nearest mm from the (National Institute for Health Research Southampton Biomedical Research Centre 2015a). Children were asked if they were happy to show their stomach. If they were unhappy to do so they were asked to hold down their vest or the layer of clothing closest to the skin. Body mass (kg) and body fat (%) were measured using leg to leg bioelectrical impedance analysis (Tanita BF305, Tanita INC, Tokyo, Japan); a piece of equipment that is valid and reliable for use in the paediatric populations (Goss et al. 2003, Jartti et al. 2000). Participants were instructed to stand still and with their eyes directly ahead of them. A single participant was measured on each piece of equipment at a time to prevent revealing sensitive and confidential information to other participants.

Body mass index (BMI) and Peak height velocity (maturation) were accounted for in subsequent analysis using anthropometric variables and age of participants. BMI was calculated (kg/m^2). Maturation was calculated following valid equations described by Mirwald et al (2002);

$Maturity\ offset$ =

Males

−9.236 + (0.0002708 × $leg\ length\ and\ sitting\ height\ interaction$) + (−0.001663 × $age\ and\ leg\ length\ interation$) + (0.007216 × $age\ and\ sitting\ height\ interaction$) + (0.02292 × ($weight\ by\ height\ ratio$)

Females

-9.376 + (0.0001882× *leg length and sitting height interaction) + (0.0022*× *age and leg length interaction*) + (0.005841×*age and sitting height interaction*) - 0.0026658× (age by weight interaction) + 0.07693×*weight by height ratio*)

5.4 Ethnicity

Ethnicity was classified by parents through self-report per classification as outlined by the Department for Education (DfE); White, Mixed/multiple ethnic groups, Asian/Asian British, Black/African/Caribbean/Black British, or other ethnic groups (National Statistics 2015).

5.5 Fundamental Motor Skills assessment Procedure

5.5.1 Process Skills assessment

Process-oriented measures are focused on movement pattern quality (Knudson and Morrison 1997). The assessment of FMS was conducted using the TGMD-2 in accordance with published research (Ulrich 2000) participants received a demonstration and verbal description of each skill. To ensure understanding, participants first completed a practice trial for each skill. If needed, an additional demonstration was given to solidify understanding. Coaching points were not provided. Two test trials were then completed by participants. Expected locomotor skill emergence/acquirement in early development guided the sequence of skill trials; skills of less complexity were trialled first as considered by Williams et al. (2009). The test trials were video-recorded (Casio video camera, EX-F1, Japan). Locomotor skills were recorded in the sagittal plane while the video-recorder was set in the coronial plane for the recording of object control skills.

Two trained researchers conducted the analysis by following two three-hour FMS-video assessment sessions (rating them against the previously rated ‘gold standard’). When the assessor agreement was >80% and differed by ≤1 unit for two test trials, training was classed as complete (Barnett et al. 2014). Intra-class correlation = 0.99, 95% CI 0.98–0.99.

The raw score for each skill component was summed and used to calculate the following as shown in detail in the *Test of Gross Motor Development Examiners Manual* (Ulrich, 2000; see Appendix 10.1):

(a) Subtest raw score; a value indicating the participant’s performance within a subtest (locomotor or object control). Both locomotor and object control subtest scores ranged from 0 to 40.

(b) Total raw score; a composite score was calculated by adding the locomotor and object control subtests, ranging from 0 to 80.

Norm values of the TGMD-2 were formulated using an American sample and previous literature has suggested that cultural differences are important in the proficiency of motor skills. Thus, to reduce the risk of misclassification in the UK sample—used in the current study—raw scores were used (Bardid et al. 2015, Bardid et al. 2016). Proficiency achievement was determined by identifying the number of components achieved for individual skills by each participant. Where the maximum number of components was achieved, a participant was classified as having mastered that skill. The percentage of the whole sample that achieved up to each number of components for each skill was then calculated (e.g. 10.59% of the sample in early childhood and 6.42% of the sample in middle childhood achieved up to 6 components of the run).

5.5.2 Product Skills assessment

Sprint speed and standing long jump distance were assessed as FMS product measures. Smart Speed Pro light gates (Fusion Sport, Coopers Plains, Australia) were used to measure sprint speed over a 10-meter distance. Participants were told to "Run as fast as they could" for each trial (one practice and two test trials), which was initiated from a standing start as described by (Ulrich 2000). Preparation commenced upon hearing "3, 2, 1" and the sprint was initiated on "GO!" Participants started standing long jump trials (one practice and two test trials) with their feet together, toes touching a horizontal line. They were told to "Jump as far as you can" before they proceeded to jump. Standing long jump distance was measured from the horizontal line to the landing position of the heel, using a long tape measure secured to the floor.

5.6 Health-related fitness assessment

Health-related fitness assessments included hand-grip strength as well as the assessment of sprint speed and standing long jump previously described (*see section 5.7.2*).

5.6.1 Handgrip strength

A paediatric hand dynamometer (Model 78011; Lafayette instrument company 1-800-428-7545) was used to assess strength through the handgrip test. Participants stood with shoulder-width apart; shoulder in 180º flexion, elbow fully extended with the wrist in supination (Roberts et al. 2011). They were then asked to "squeeze" the dynamometer "as tightly as possible" while adducting the shoulder and maintaining full extension of the elbow (Roberts et al. 2011). Each participant was provided with a demonstration before their first trial. Three trials were completed using the dominant hand, interspersed with one minute rest periods (Roberts et al. 2011); average and peak grip strength was calculated (Häger-Ross and Rösblad 2002). There is a strong correlation between grip strength and whole-body strength in the paediatric population (Wind et al. 2010).

5.7 Data collection

The Principle Investigator allocated a number to each participant to ensure data was anonymised, and that all measures linked to the correct participant. Data was stored in a locked cabinet and on an encrypted external hard-drive. Data handling and destruction procedures were conducted as guided by the Caldicott principles and data protection act 1998, and General Data Protection Regulation 2018.

All data collection for *Studies One, Two* and *Four* was conducted in primary school halls during PE lessons for anthropometric measures, FMS, and health-related fitness measures. The hall was split into two sections. Section one consisted of locomotor skills (inclusion of skills dependent upon study) and section two included object control assessment (inclusion of skills dependent upon the study), anthropometric measures as well as strength measures for *Study Three*. Assessments were conducted in this way to ensure efficiency; completion within the allotted session time, and to ensure all skills were recorded in the appropriate planes and were visible for subsequent analysis. Perceived ability to perform FMS was carried out on a one-to-one basis with each participant outside their classroom, to reduce the likelihood of distraction and influence of others.

6.0 STUDY ONE: FUNDAMENTAL MOTOR SKILLS OF CHILDREN IN DEPRIVED AREAS OF ENGLAND: A FOCUS ON AGE, GENDER AND ETHNICITY.

6.1 Thesis Map

Table 6.1. Thesis map 6.0

STUDY	AIMS	OBJECTIVES
Study One: ***"Fundamental motor skills of children in deprived areas of England: a focus on age, gender and ethnicity."***	**To asses FMS mastery of males and females' children schooling in deprived ethnically diverse areas in England.**	• **To examine process and product FMS of males and females in early and middle childhood.** • **To compare process and product measures of FMS in males and females as well as Black, White and Asian ethnicities between and within children in early and middle childhood.**
Study Two: *"The mediating roles of perceived motor competence and health-related fitness for children's physical activity."*	To examine factors affecting motor competency and moderate to vigorous physical activity engagement. Exploring and objective context for study one.	• To examine FMS, MVPA, PMC and HRF during early and middle childhood. • To assess the indirect associations between FMS and MVPA bi-directionally through PMC and HRF during early and middle childhood.
Study Three: *"Barriers and facilitators of FMS development, pa engagement and PE: a primary school teacher's perspective."*	To explore a Teachers perspective of FMS development, PA engagement and PE curriculum in England. To provide additional context of study one and inform study four.	• To identify the perceptions and suggestions of the following topic of teaching staff in schools located in deprived ethnically diverse areas: o PA and PE in England o Barriers and facilitators of PA and motor development o PE within the curriculum and the delivery of PE o Training for PE o Incorporating PE specialists in the delivery of PE
Study Four: *"The effect of integrative neuro muscular training on fundamental motor skills and health-related fitness in nine-to-ten-year-old"*	To assess the effect of a 6-week INT programmed on FMS and HRF measures in nine-to-ten-year-old males and females at pre-, post and post-6-week intervention period.	• To asses FMS and HRF measures at baseline • To implement a 6-week INT programme • To assess FMS and HRF measures immediately post the intervention programme To assess FMS and HRF measures post 6-weeks intervention

6.2 Abstract

This study compared the mastery of fundamental motor skills (FMS) of males and females in early childhood (four to five years, n = 170) and middle childhood (nine to ten years, n = 109) who attend schools in deprived and ethnically diverse areas of England. Process FMS (object control and locomotor skills) were observed using the Test of Gross Motor Development-2. Sprint speed over 10 meters and jump distance assessments were conducted using light gates and tape measures. A gender (male vs. female) by year-group (early childhood vs. middle childhood) interaction was shown for the process and product-oriented FMS measurements. Middle childhood males and females demonstrated significantly greater FMS mastery, as compared to early childhood ($p < 0.05$). Furthermore, middle childhood males demonstrated significantly greater mastery of total FMS, object control skills, and product-oriented assessments, in comparison to females ($p < 0.05$). Children of Black and White ethnic groups achieved significantly greater mastery of locomotor skills, compared to Asian children, though this did not differ by year-group ($p < 0.05$). The results suggest that FMS development in deprived and ethnically diverse areas in England varies between genders during middle childhood and ethnicity. Thus, interventions addressing the lack of FMS mastery achievement, shown in middle childhood girls and children from Asian ethnic backgrounds, may be pivotal. Further exploration of the role of ethnicity would provide greater clarity in approaching interventions to improve FMS.

6.3 Introduction

Regular PA engagement during childhood is essential for lifelong physiological, psychological, cognitive, and social development (Janssen and LeBlanc 2010). However, children from as early as five years old in England demonstrate inactive lifestyles (Townsend et al. 2015), and this inactive behaviour increases with age (Townsend et al. 2015, Scholes 2016, World Health Organisation 2017). Engagement in PA during adolescence and into adulthood is, in part, impacted by a child’s mastery level of FMS (Lubans et al. 2010); where high FMS ability promotes a more physically active lifestyle and a low FMS ability promotes a more sedentary lifestyle (Lubans et al. 2010). The acquisition of

FMS initiates during infancy and are expected to be commonly acquired by the age of five to six years (Gallahue, Ozmun and Goodway 2012, Haywood and Getchell 2014). The acquiring of skills indicates that high proficiency is not expected. While this is reflected in that most children aged five to six years demonstrate ‘poor’ skill proficiency in England (Eyre et al. 2018, Duncan et al. 2019). Specific information regarding individual components of skills is limited, thus inhibiting the ability to observe if skills are actually acquired around this age irrespective of the proficiency level (e.g. at least one component of each skill is achieved by the majority of children aged five to six years old). Describing skills as ‘poor’ is determined where a skill is performed with two or more incorrect components (O’Brien, Belton and Issartel 2016), thus children may have not achieved any components/not performed the skill or have achieved all but two components and both would be classified as ‘poor’ indicating they may have acquired the skill. Children then enter into a phase of transition (seven and ten years), where acquired skills are expected to be mastered and become more context-specific—such as in sporting situations (Gallahue, Ozmun and Goodway 2012). FMS acquisition does not develop naturally or automatically, it must be taught based on age and stage of learning and should be practiced and reinforced (Riethmuller, Jones and Okely 2009, Logan et al. 2012, Morgan et al 2013). The development of FMS has been reported to differ between children from different countries (Bardid et al. 2015), although ethnicity is rarely reported/considered in the analysis (Chow, Henderson and Barnett 2001, Okely, Boothand Chey 2004, Bardid et al. 2015, Morley, Ogilvie and Turner 2015, Bardid et al. 2016). Newell’s constraints theory (Newell1986) highlights the influence of individual, environmental, and task constraints on motor development. Several different constraints, such as deprivation, PA engagement levels, and obesity have been shown to relate to ethnicity and FMS exclusively, but have rarely been considered together (Lopes et al. 2011, Eyre and Duncan 2013, Falconer et al. 2014, Robinson et al. 2015). For example, research suggests that children in low-socioeconomic (SES) areas perform FMS at a significantly lower level than those in high-SES areas in England (Morley, Ogilvie and Turner 2015). Within England, there is a greater likelihood that ethnic minority groups will live in deprived neighbourhoods (Jivraj and Khan 2013). Understanding the differences in FMS mastery of children from different ethnic backgrounds, and the constraints relating to it, may further complete the research-base; providing greater insight into FMS development and subsequently PA engagement and future health, particularly within low-SES communities. The current study seeks to address key gaps in the FMS literature relating to age, gender, and ethnicity while considering deprivation and the controlling of maturation and BMI; examining differences in FMS mastery achievement of early childhood (four-to-five-years) and middle childhood (nine-to-ten-years) males and females from different ethnic groups.

6.4 Method

Study design

An observational study design was employed in study one to explore FMS performance ability (process and product scores) of children in reception (four-to-five-years-old) and year 5 (nine-to-ten-years-old) in a deprived area from different ethnic backgrounds. The processed FMS data collected for study one was also used in conjunction with PMC, HRF and PA engagement data collected to conduct a mediation analysis in *Study Two* (*see section 7.4*).

Sample selection

Headteachers and PE coordinators were contacted regarding participation in the study. A meeting was organised between the principal investigator, headteacher and/or PE coordinator to discuss the study. The meeting entailed a full overview of the project aims and objectives and requirements of participants (parental consent, ascent and activities during the study) and any questions were answered.

If schools were willing to participate, class teachers and teaching support staff of Reception and Year five were informed of the study. Information letters and consent forms were distributed to parents/guardians of pupils in the relevant year groups, providing parents/guardians with the opportunity to contact the principal investigator to answer any questions. The informed consent form also required parents/guardians to report information on their child’s age, birth month, sex and ethnicity. Two weeks was arranged for consent forms to be returned, after which assessment days were organised with PE coordinators and class teachers. Participants were excluded post-parental consent if they were not physically able to participate due to physical inability (e.g. broken bones, severe asthma, illness) or wanted to withdraw. Analysis was only conducted on data collected from participants who provided data for all measures.

Anthropometric data

Please refer to section *5.3*

Process-oriented assessment of Fundamental Motor Skills

Please refer to section 5.5.1

Product-oriented assessment of Fundamental Motor Skills

Please refer to section 5.5.2

Statistical analysis

The final population included within the analysis consisted of 170 (58%) children in early childhood (87 males; 4.92 ± 0.26 years, White 66, Asian 73, Black 31) and 109 (67%) children in middle childhood (60 males; 9.6 ± 0.49 years, White 34, Asian 45, Black 50; *see Table 6.2*). Process-oriented FMS performance ability (total, object control and locomotor skills) and product-oriented FMS performance ability of children (males and females) in early and middle childhood were observed. Means and SD's were calculated for all variables. Participant's data were excluded if they were of a mixed ethnic background, exhibited developmental delays (e.g. sever special education needs, motor control/development delays), not all the data previously stated was collected and analysed or they or their parent/guardian no longer wished to participate. A total of 175 participants (early childhood; 123 and middle childhood; 52) were removed from this study.

IBM SPSS Statistics software (v.24 IBM Corp Amork USA) was used to conduct a two (early childhood vs. middle childhood) by two (males vs. females) by three (White vs. Asian vs. Black) ways between groups multivariate analysis of covariance (MANCOVA) was conducted. Assumptions regarding normality and homogeneity of variance were not violated. Maturation (years from and age at maturation) and BMI were used as covariates due to previous observations showing the influence of maturation on FMS performance ability in children and the apparent inverse relationship between FMS and weight status (overweight/obese; Moody et al. 2014, Robinson et al. 2015). Maturation and BMI were not significant covariates of total FMS (p=0.75 and p =0.77) object control (p= 0.32 and p=0.42), locomotor skills (p =0.45 and p =0.72) proficiency or composite product score (p=0.20 *and* p=0.26) in the population of the current study. Therefore, they were removed from the analysis and subsequent Multivariate analysis of Variance (MANOVA) was carried out. Bonferroni post-hoc analysis was carried out to identify where any significant differences existed, and the effect size was used to identify the magnitude of the differences. The effect size was calculated using the following Cohens-*d* calculation (*d*; Lakens 2013): $d = (Mean_2 - Mean_1) \div SD_{pooled}$

6.5 Results

Overall, children demonstrated moderate-to-low levels of FMS proficiency and mastery (*Tables 6.3a, 6.4 and Figures 6.3a-c, 6.4a)*. The results of the MANOVA, for process and product-oriented FMS, revealed a significant gender (male vs. female) by childhood year (early vs. middle) interaction (*Figure 6.1*). A post-hoc pairwise comparison (Bonferroni adjusted) identified the total FMS mastery of males and females in middle childhood to be significantly better than early childhood males and females (F(1,267) = 7.27, p = 0.007; M1 − M2 = 22.02, 95% CI (21.12, 21.81) and M1 − M2 = 16.20, 95% CI (15.47, 16.47), *Figure 6.1*). Middle childhood males and females also performed object control skills significantly better than early childhood males and females (F(1,267) = 5.99, p = 0.02; M1 − M2 = 13.39, 95% CI (13.01, 13.39) and M1 − M2 = 10.21, 95% CI (9.76, 10.22), *Figure 6.1*).

Table 6.2. Participant demographic variables by year group and gender.

	All (Mean ± SD)	Early Childhood (Mean ± SD)		Middle Childhood (Mean ± SD)		Ethnicity (Mean ± SD)		
		Males	**Females**	**Males**	**Females**	**Black**	**White**	**Asian**
N	279	87	83	60	49	61	100	118
Age (years)	6.76 ± 2.32	4.93 ± 0.26	4.93 ± 0.26	9.60 ± 0.49	9.60 ± 0.49	7 ± 2.30	7 ± 2.32	7 ± 2.31
Standing Height (cm)	122.20 ± 15.96	111.10 ± 6.29	111.10 ± 6.33	139.71 ± 9.83	139.52 ± 9.96	122.10 ± 16.01	122.3 ± 16.01	122.2 ± 16.01
Seated Height (cm)	62.64 ± 6.57	58.09 ± 3.11	58.09 ± 3.13	69.82 ± 3.50	69.73 ± 3.54	62.60 ± 6.58	62.7 ± 6.59	62.6 ± 6.59
Mass (kg)	26.51 ± 10.27	19.89 ± 3.61	19.91 ± 3.62	37.06 ± 8.56	36.83 ± 8.75	26.48 ± 10.30	26.6 ± 10.30	26.5 ± 10.30
BMI (kg/m^2)	17.18 ± 3.61	16.03 ± 1.84	16.04 ± 1.84	19.05 ± 4.79	18.98 ± 4.83	17.18 ± 3.61	17.2 ± 3.61	17.2 ± 3.62
Waist Circumference(cm)	53.51 ± 11.06	52.02 ± 3.95	52.01 ± 3.96	56.03 ± 16.94	55.75 ± 16.97	53.7 ± 12.18	52.42 ± 10.95	54.3 ±10.59

Additionally, composite product scores also showed a gender by childhood year interaction ($F(1,267) = 5.95$, $p = 0.02$), where males and females in middle childhood outperformed those in early childhood ($M1 - M2 = 0.64$, 95% CI (0.36, 0.99) and $M1 - M2 = -0.06$, 95% CI (−0.36, 0.39), *Figure 6.2*. There was a significant childhood year (early childhood vs. middle childhood) by gender (males vs. female) interaction for both process mastery and the product-oriented performance of children in middle childhood, but not for those in early childhood. Gender differences were shown in the total FMS mastery of males and females in middle childhood ($M1 - M2 = 5.87$, 95% CI (6.43, 5.34), $r = 0.93$); $p < 0.05$, *Figure 6.1*). Males also demonstrated significantly better object control skills ($M1 - M2 = 4.27$, 95% CI (4.59, 4.09), $p < 0.05$, Figure 1) and composite product score ($M1 - M2 = 0.56$, 95% CI (0.58, 0.51), $p = 0.02$, *Figure 6.2*). Overall, children in middle childhood significantly outperformed children in early childhood in total FMS ($M1 - M2 = 19.4$, 95% CI (18.43, 18.91), $p < 0.01$), object control raw score ($M1 - M2 = 12.00$, 95% CI (11.45, 11.75), $p < 0.01$), locomotor raw score ($M1 - M2 = 7.4$, 95% CI (6.94, 7.22), $p < 0.01$), and composite product score ($M1 - M2 = 0.32$, 95% CI (0.10, 0.59), $p < 0.01$). As shown in *Tables 6.3 and 6.4*, a greater percentage of children in middle childhood achieved all components across locomotor and object control skills. The run, leap, and gallop are shown to have had the greatest percentage achievement of all locomotor skills components (67.89%, 56.88%, and 38.5%, respectively), while object control skills were the highest in catch (85.32%), strike (50.46%), and overarm throw (37.61%). However, no skill was mastered by the entire middle childhood sample.

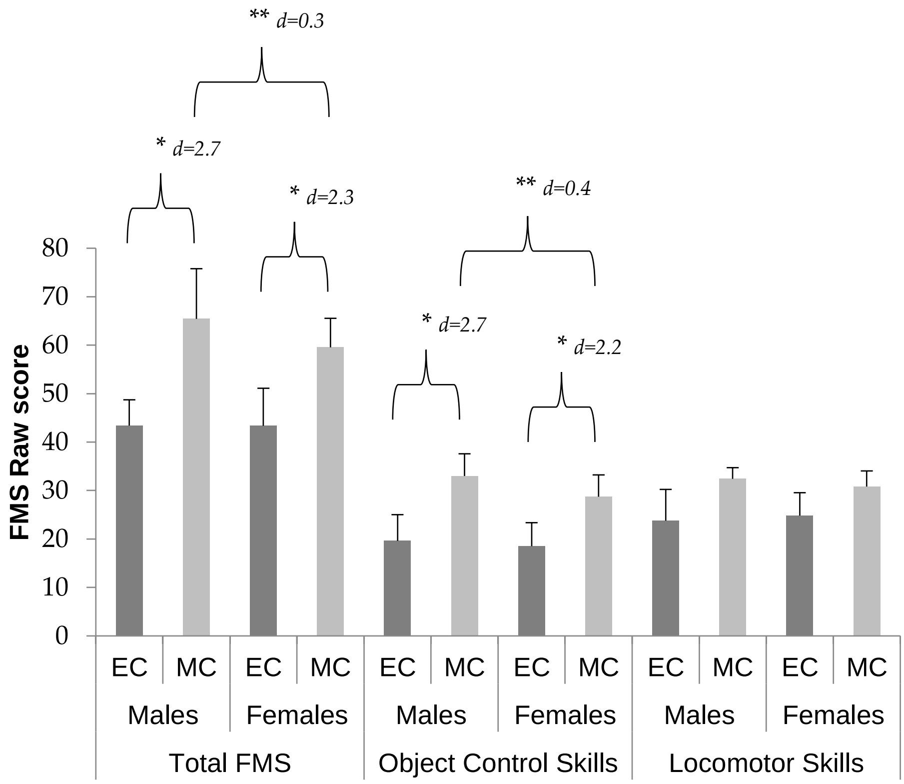


Figure 6.1. *Total Fundamental Motor Skills and object control skill proficiency scores (mean ± standard deviation) of males and females in early and middle childhood. * indicates a significant difference between age groups (P <0.05). **indicates a significant difference between males and in middle childhood (P <0.05).*

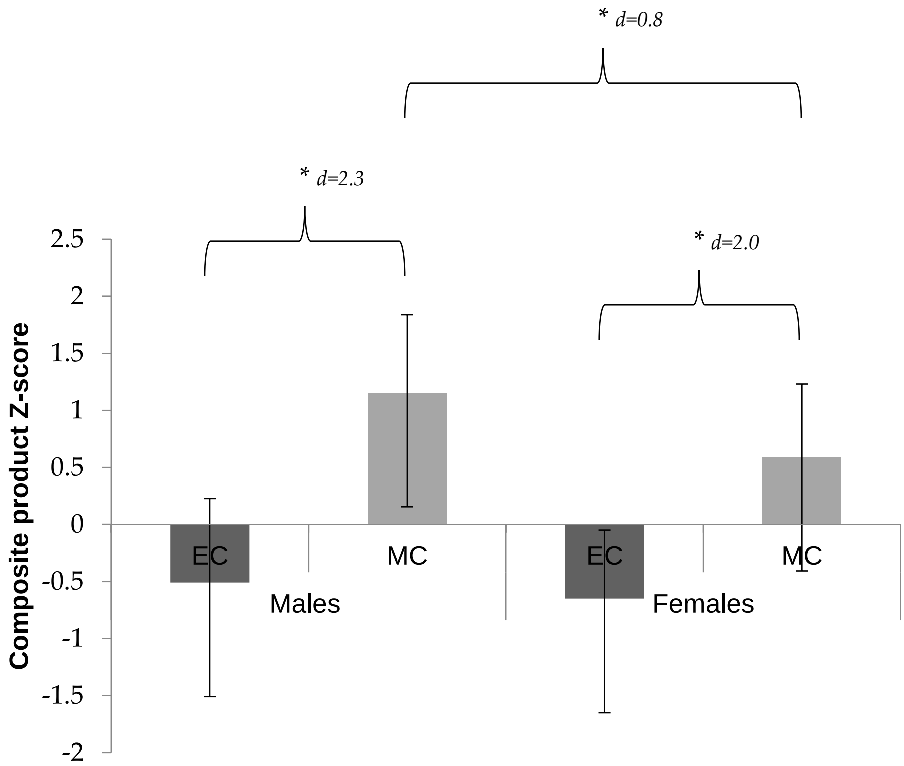


Figure 6.2. *Composite product Z-score (mean ± standard deviation) of early childhood (EC) and middle childhood (MC) males and females. * indicates a significant difference between early childhood and middle childhood (P <0.05); * indicates a significant difference between males and females within a year group (P <0.05).*

Table 6.3. Component achievement (%) of locomotor skills during early childhood (EC) and middle childhood (MC).

Components Achieved	Run (%)		Gallop (%)		Hop (%)		Leap (%)		Jump (%)	
	EC	**MC**	**EC**	**MC**	**EC**	**MC**	**EC**	**MC**	**EC**	**MC**
0	0.59	0.00	4.71	0.00	7.06	0.00	2.35	0.00	4.12	0.92
1	0.00	0.00	1.18	0.00	1.76	0.00	2.94	0.00	2.35	0.92
2	2.94	0.00	8.82	5.50	4.71	0.00	15.88	1.83	21.76	2.75
3	3.53	0.00	8.82	0.92	5.88	0.92	7.65	3.67	13.53	0.92
4	9.41	0.92	19.41	2.75	17.65	3.67	24.12	18.35	32.35	17.43
5	8.82	1.83	8.24	7.34	8.82	6.42	12.94	19.27	8.82	7.34
6	30.00	5.50	22.94	33.03	25.29	33.03	34.12	56.88	12.35	47.71
7	20.59	14.68	12.35	11.93	11.76	21.10			1.76	9.17
8	24.12	67.89	13.53	38.53	17.06	34.86			2.94	13.76
9					0.00	0.00				
10					0.00	0.00				[1]

[1] Mastery of a skill was identified where participants achieved the maximum number of components within a skill.

Table 6.4. Component achievement (%) of object control skills during early childhood (EC) and middle childhood (MC).

Components Achieved	Strike (%)		Bounce (%)		Catch (%)		Overarm Throw (%)		Roll (%)	
	EC	MC	EC	MC	EC	MC	EC	MC	EC	MC
0	0.59	0.00	32.35	3.67	3.53	0.00	12.35	1.83	5.88	1.83
1	0.59	0.00	13.53	1.83	2.94	0.00	4.12	0.00	4.12	1.83
2	2.94	0.92	25.88	3.67	17.06	0.00	27.06	12.84	18.82	8.26
3	4.71	0.00	7.06	5.50	15.88	0.00	12.94	3.67	14.12	11.01
4	8.24	0.92	12.35	15.60	37.06	11.01	17.06	6.42	37.65	25.69
5	7.65	1.83	4.71	8.26	15.88	3.67	8.24	7.34	12.94	11.93
6	10.59	6.42	2.35	17.43	7.65	85.32	10.59	17.43	4.12	24.77
7	19.41	3.67	0.59	11.93			1.76	12.84	1.18	4.59
8	25.29	17.43	1.18	32.11			5.88	37.61	1.18	10.09
9	11.18	18.35								
10	8.82	50.46								

When the sample was categorised by ethnicity, a main effect was indicated for locomotor skills (p = 0.012; *Figure 6.3a-c*). A Bonferroni adjusted post-hoc pairwise comparison indicated similar mastery by Black and White children (Black vs. White; M1 − M2 = 1.55, 95% CI (0.19, 0.72)). Children of both Black and White ethnic groups demonstrated better locomotor skills, compared to Asian children (Black vs. Asian; M1 − M2 = 3.13, 95% CI (1.66, 2.41), White vs. Asian; M1 − M2 = 1.58, 95% CI (1.47, 1.69)). Considering the components of locomotor skills, achieved by participants (*Figure 6.4a-b*), children of a Black and Asian ethnic background achieved the greatest percentage of mastery in the leap (55.47%, 37.29%). White children had the greatest achievement of components in the run (47%). Additionally, Black, Asian, and White children all had the greatest component achievement (mastery) in the catch (55.74%, 39.83%, and 39%). Across all ethnicities, no skill was mastered, and the hop and the roll were the least mastered skills by all participants (*Figures 6.3a-c and 6.4a-b*). There were no significant differences between children of different ethnicities in their performance of product-oriented measures.

Figure 6.3a. Component achievement (%) of locomotor skills by ethnicity; Run.

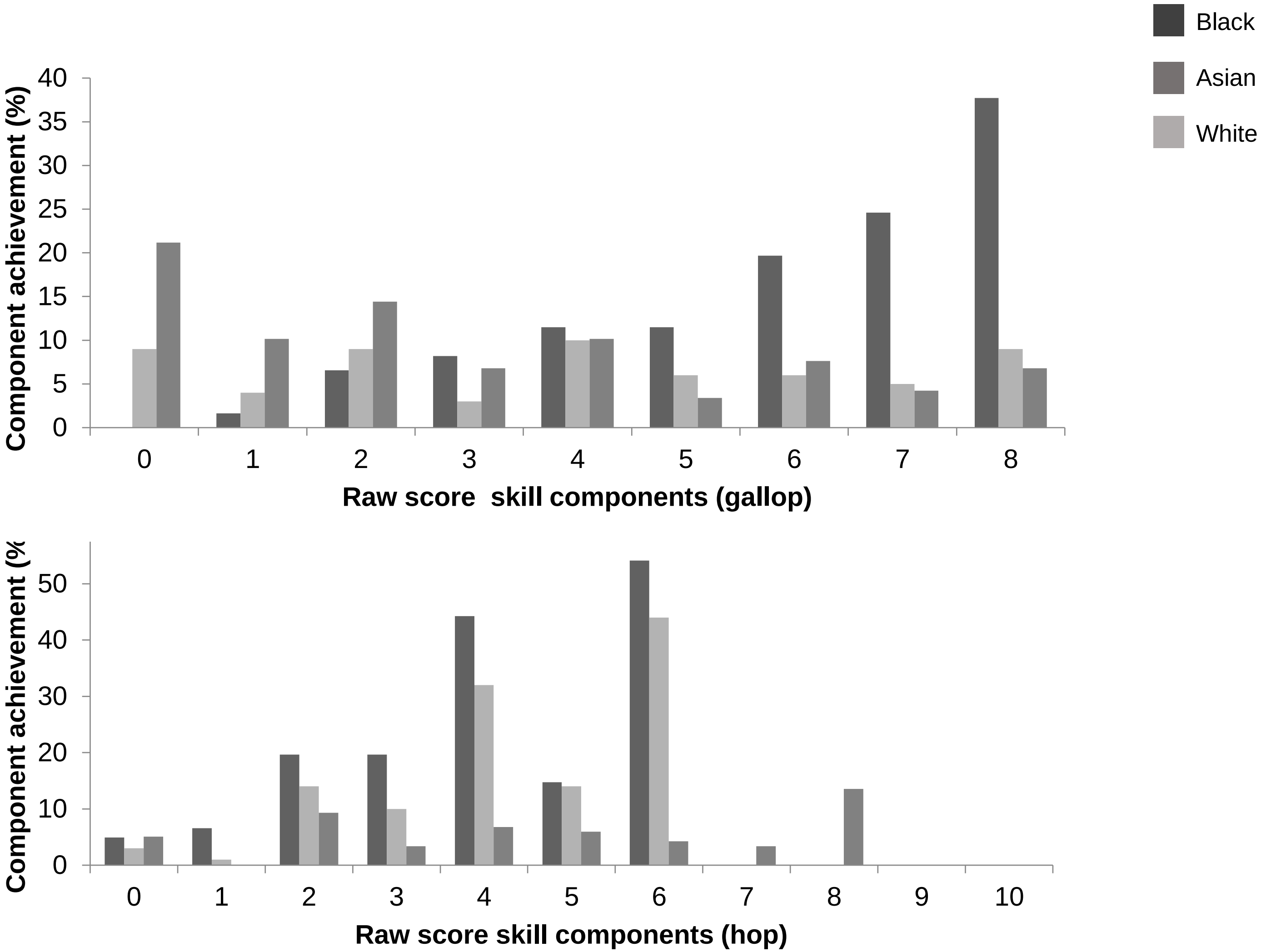


Figure 6.3b. Component achievement (%) of locomotor skills by ethnicity; Hop; and Gallop.

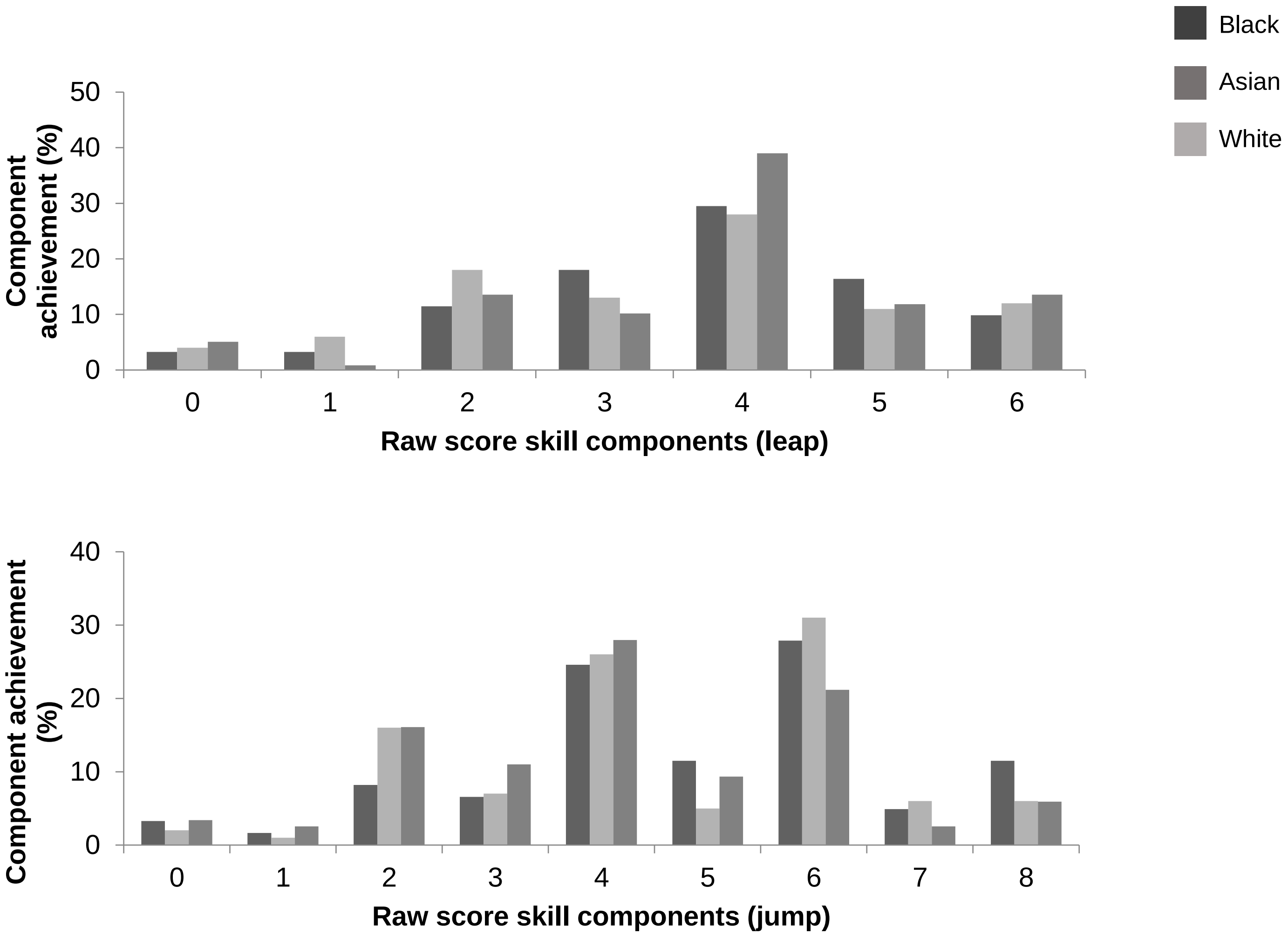


Figure 6.3c. Component achievement (%) of locomotor skills by ethnicity; Leap and Jump.

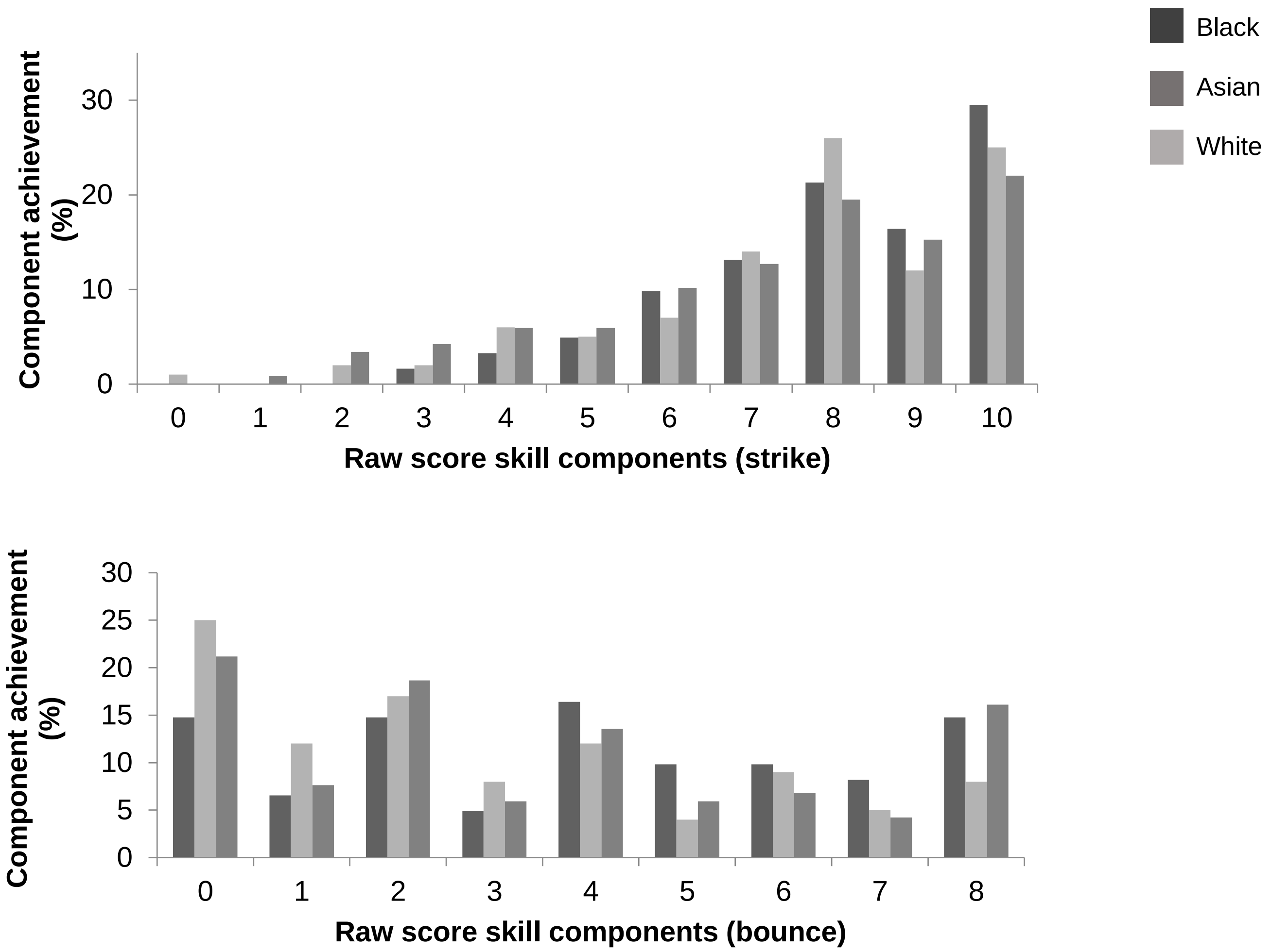


Figure 6.4a. Component achievement (%) of object control skills by ethnicity; Strike and Bounce.

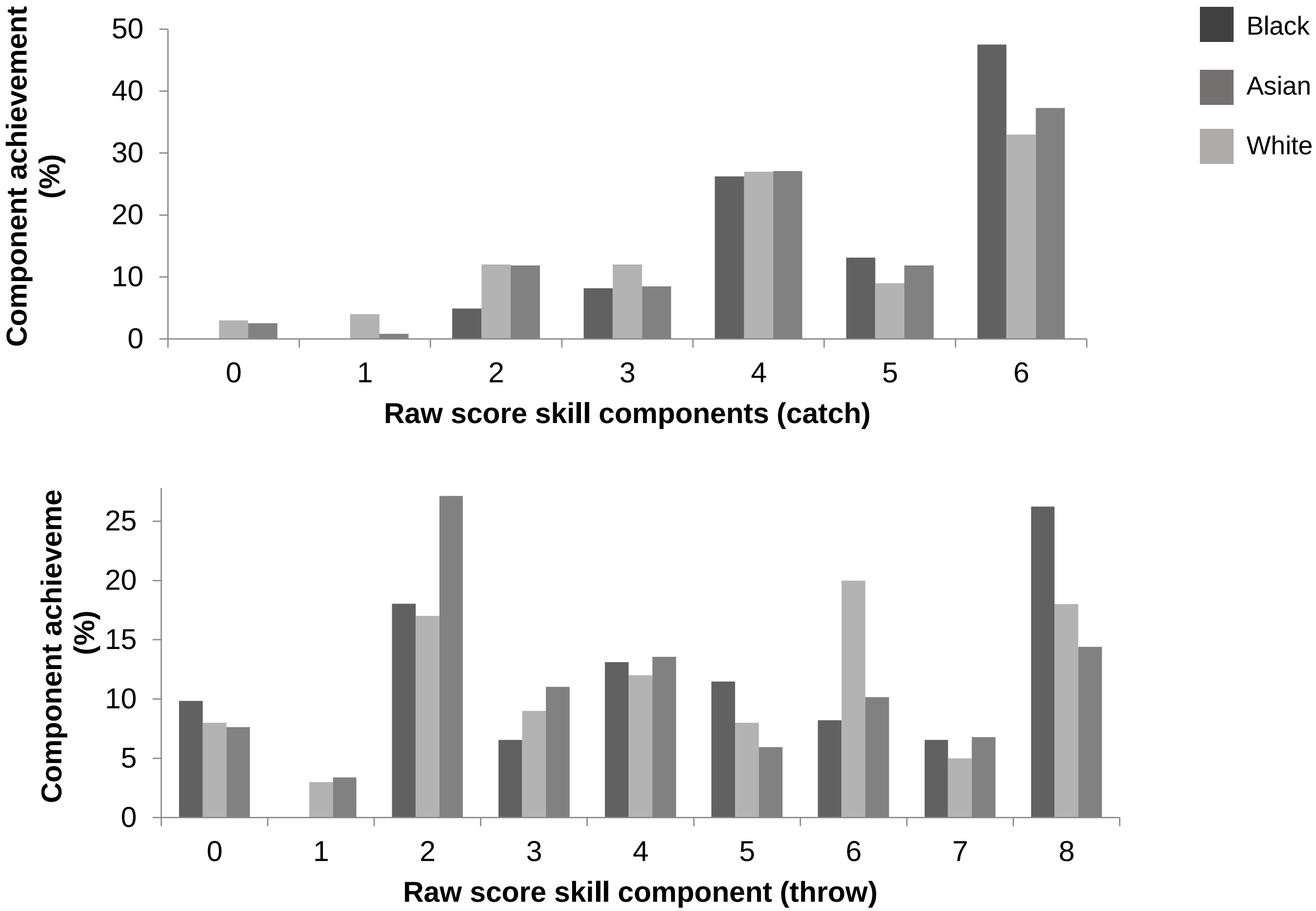


Figure 6.4b. Component achievement (%) of object control skills by ethnicity; Catch and Throw.

6.6 Discussion

This study sought to identify differences in the process and product FMS ability of children in early and middle childhood who attend schools in deprived and ethnically diverse areas in England—while considering gender and ethnic background. Novel data are presented through assessing children in the acquisition phase in early childhood and at the end of the transitional stage in middle childhood of FMS development in England, comparing year group, gender, and ethnicities between and within these groups. The key finding from this study is that children from Black and White ethnic backgrounds performed significantly better for locomotor skills, compared to Asian children, irrespective of childhood stage. Eyre et al. (2018)'s work is the only study to have observed the role of ethnicity and FMS in five-year-olds, reporting that South Asian children demonstrated poorer total FMS and locomotor skills, compared to Black and White children. The current study extends the work of Eyre et al. (2018), showing that the ethnic differences in locomotor skills reported also persist in middle childhood. Across developmental time, FMS have been suggested to be impacted by a combination of multiple interlinking constraints relating to the individual, their environment, and the task at hand (Newell 1986). These may include exposure to, and experience of, PA engagement; children from South Asian backgrounds living in England have the greatest percentage of children failing to meet the UK PA recommended guidelines for health, compared to their Black and White counterparts (Owen et al. 2009, Eyre et al. Duncan 2013, Bhatnagar et al. 2016). Thus, Asian children may experience less opportunity for FMS to be practiced and reinforced (eight-to-ten). Secondly, social interactions and the influence of cultural norms/expectations, encouragement from significant others/role models, and/or what their family/friends engage in within different ethnic communities. Constraints may also be found in the community environment (e.g., socio-economic status), the lack of safe open spaces, and the equipment available for engagement/practice—as well as finances available for equipment and clubs/projects engagement (Sallis et al. 2000, Van Der Horst et al. 2007). Thus, FMS development relating to ethnicity may be multifaceted, with Asian children undertaking greater constraints during childhood than Black and White children resulting in the lack of mastery achievement seen in the current study. The current findings develop the limited research in the UK surrounding ethnicity and deprivation, though it is clear that further investigation is necessary.

While ethnic differences did not differ by age, the current study also showed greater mastery of skills from children in middle childhood compared to those in early childhood although, overall mastery attainment was low complementing the literature (Foweather 2010, Foulkes et al. 2015, Robinson et al. 2015). A main founding pillar of FMS development is the need for teaching, practice, and the reinforcement of skills (Morgan et al. 2013). Therefore, within the current study, as older children are expected to be in the latter transitional stages of the PE curriculum in England, having greater engagement by being taught and practicing skills may have, in part, facilitated FMS development (DfE 2017). If PE is engaged in there may be greater potential for strengthening the synaptic pathways and motor control strategies and the experience of synaptic pruning over a greater period in middle childhood, compared to children in early childhood (Moody et al. 2014). However, the effectiveness of PE delivery/engagement is challenged as although children in middle childhood outperformed those in early childhood, a deficit in mastery was still present in the current study. It should still be considered that the rate of each child's progression through the developmental phases and stages are individual, and that development is related to age but not necessarily dependent upon it (Gallahue, Ozmun and Goodway 2012). When comparing mastery achievement of participants in the current study to the TGMD-2 standardization sample (Ulrich 2000), the limited achievement is proposed in both age groups—particularly the children in middle childhood as they are all expected to have mastered FMS. The only skills to show a greater percentage mastery achievement was the leap during early childhood and middle childhood (+20.12% and +6.88%), as well as the strike and catch during MC (+1.46% and +2.32%). Mastery of all other skills in the current study was below the percentage achieved by the standardized sample (Ulrich 2000). This comparison should be considered with caution, as there are differences in FMS mastery across different countries and that the standardisation sample was based in America (Ulrich 2000, Bardid et al. 2015). However, low levels of FMS proficiency found in the current study are supported by research conducted in both deprived and ethnically diverse cohorts in the United Kingdom (Foweather 2010, Foulkes et al. 2015, Eyre et al. 2018). Constraints that negatively impact FMS development are identified within three domains (*individual, environmental and task*; Newell 1986). The voluntary nature of FMS means that development is ultimately dependent upon the impact experienced within the domains on a child being taught skills as well as their learning and practice of those skills (Logan et al. 2012, Morgan et al. 2013). Thus, where low proficiency is demonstrated, as in the current study, broadly an insufficient process of teaching, learning and/or repetition is indicated. The interaction between these processes and the impact constraints experienced by this group (deprived and ethnically diverse) have on them is complex. Due to the limited exploration of proficiency levels and constraints specifically related to this group further investigation is needed and provides the basis for *Study Two and Three*.

Sex differences were also highlighted in the current study, with middle childhood males performing better than females in total FMS and object control skills, aligning with much of the literature (Morley et al. 2015, Venetsanou and Kambas 2016). This has previously been attributed to males being more physically active than females and being encouraged during early childhood to engage in ‘masculine’ activities (e.g., football; Haywood and Getchell 2014). Furthermore, males have been found to engage in PA with greater use of ball control elements, compared to the rhythmic and balance elements engaged in by females (Maturo and Cunningham 2013). Considering this and the findings that show childhood playmate selection is often based on sex (Martin et al. 2013), contributing factors to the differences in mastery attainment between sexes vary from individual to individual as well as social and environmental constructs. Locomotor skills of males and females were not significantly different in the current study. Before analysis adjustments, previous observations have shown males of a similar age, mainly from areas of high deprivation, to have significantly greater proficiency of locomotor, object control and Total FMS (McWhannell et al. 2018). However, this significant difference in locomotor motor skill proficiency was removed when the analysis was conducted adjusting for age, ethnicity, deprivation, maturity offset and percentage body fat (McWhannell et al. 2018). After which the findings reflected those in the current study. Due to the variations in relationships shown between sex and locomotor skills, it is challenging to substantiate this finding (Robinson et al. 2015) although, where a similar sample (multi-ethnic children from low socio-economic areas in the UK) and methods were used by Eyre et al. (2018) no sex differences were also found in locomotor skills of children in early childhood. Sex similarities propose that males and females in these deprived and ethnically diverse areas may undergo fewer differences regarding constraints relating to locomotor skills and the rate of FMS development may be comparable. It should also be noted that studies that have found differences in locomotor skills differ in FMS assessment tools, populations (age, ethnicity), geographical location/environment, and subsequently societal norms/expectations as well as the SES from the current study. Thus, the present findings broaden the understanding of the low FMS mastery attainment of children in England and its relation to ethnicity and deprivation.

As in much of the literature, the current study presents its own limitations and strengths. Firstly, the cross-sectional nature of the study means that the level and rate of FMS developmental progression from early to middle childhood could not be observed. Future research should aim to conduct longitudinal research to provide a broader picture of FMS development across developmental time. This will subsequently inform FMS interventions concerning gender-specific time points as well as possible ethnic patterns/trends if any. Additionally, deprivation was accounted for in relation to the school attended by participants. Further, specification of post-codes lived in by participants along with the comparison between ethnically diverse schools in high and low-SES areas may provide greater scope and understanding of varying FMS mastery achievement by SES and the ethnicities within them.

6.7 Conclusion

The current study develops the sparse research base relating to ethnicity and FMS; when deprivation, maturation, and obesity are controlled for lack of mastery achievement, it is present in Black, White, and Asian children, overall. Moreover, Black and White children in early and middle childhood seem to be more proficient in FMS than those from Asian ethnic backgrounds. Future research would benefit from further investigation of the FMS constraints highlighted in the literature (Stodden et al. 2008), and in relation to ethnicity, the categorizing of sub-groups within ethnicities. Despite the sample of the current study not being big enough to conduct a subgroup analysis, this line of investigation may further distinguish findings relating to FMS within ethnic groups. Highlighting these may help inform interventions targeting groups that display a reduced mastery achievement that was expected to reduce the proficiency gap and subsequently improve the health trajectories of children.

6.8 Thesis Map 6.1

Table 6.5. Thesis map 6.1.

STUDY	AIMS	OBJECTIVES
Study One: *"Fundamental motor skills of children in deprived areas of England: a focus on age, gender and ethnicity."*	To asses FMS mastery of males and females children schooling in deprived ethnically diverse areas in England.	• To examine process and product FMS of males and females in early and middle childhood. • To compare process and product measures of FMS in males and females as well as Black, White and Asian ethnicities between and within children in early and middle childhood.

KEY FINDINGS:

- Children in middle childhood had a significantly greater mastery of total FMS, object control, locomotor skills and product scores than children in early childhood.
- Boys in middle childhood demonstrated significantly greater mastery of total FMS, object control skills and product scores than their female counterparts.
- Children of black and white ethnic backgrounds had significantly greater locomotor skill mastery than those of Asian ethnic backgrounds.

7.0 STUDY TWO: THE MEDIATING ROLES OF PERCEIVED MOTOR COMPETENCE AND HEALTH-RELATED FITNESS FOR CHILDREN'S PHYSICAL ACTIVITY.

7.1 Thesis Map

Table 7.1. Thesis map 7.0

STUDY	AIMS	OBJECTIVES
Study One: *"Fundamental motor skills of children in deprived areas of England: a focus on age, gender and ethnicity."*	To asses FMS mastery of males and females' children schooling in deprived ethnically diverse areas in England.	• To examine process and product FMS of males and females in early and middle childhood. • To compare process and product measures of FMS in males and females as well as Black, White and Asian ethnicities between and within children in early and middle childhood.
Study Two: *"The mediating roles of perceived motor competence and health-related fitness for children's physical activity."*	**To examine factors affecting motor competency and moderate to vigorous physical activity engagement. Exploring and objective context for study one.**	• **To examine FMS, MVPA, PMC and HRF during early and middle childhood.** • **To assess the indirect associations between FMS and MVPA bi-directionally through PMC and HRF during early and middle childhood.**
Study Three: *"Barriers and facilitators of FMS development, pa engagement and PE: a primary school teacher's perspective."*	To explore a Teachers perspective of FMS development, PA engagement and PE curriculum in England. To provide additional context of study one and inform study four.	• To identify the perceptions and suggestions of the following topic of teaching staff in schools located in deprived ethnically diverse areas: ○ PA and PE in England ○ Barriers and facilitators of PA and motor development ○ PE within the curriculum and the delivery of PE ○ Training for PE ○ Incorporating PE specialists in the delivery of PE

Study Four: *"The effect of integrative neuro muscular training on fundamental motor skills and health-related fitness in nine-to-ten-year-old"*	To assess the effect of a 6-week INT programmed on FMS and HRF measures in nine-to-ten-year-old males and females at pre-, post and post-6-week intervention period.	• To asses FMS and HRF measures at baseline • To implement a 6-week INT programme • To assess FMS and HRF measures immediately post the intervention programme To assess FMS and HRF measures post 6-weeks intervention

7.2 Abstract

The association between PA and FMS is suggested to be mediated by PMC and HRF, influencing a child's health trajectory; positively (healthy weight) or negatively (overweight/obesity) though supporting literature is scarce. This study sought to investigate mediation between MVPA and FMS through PMC and HRF in early childhood and middle childhood. Following institutional ethical approval, 133 participants (early childhood: 55, 4.93±0.25-years-old; middle childhood: 77, 9.62±0.49-years-old) data was analysed. PA data was collected using accelerometers (ActiGraph-wGT3X-BT, USA). The Test of Gross Motor Development-2 assessed FMS. PMC was evaluated using The Pictorial Scale of Perceived Movement Skills Competence for Young Children4. HRF (compound-z-score) included 10m sprint-speed, standing long-jump and strength, measured using light gates (Fusion Sport, Coopers Plains, Australia), tape measures and a paediatric hand-dynamometer (Model78011; Lafayette instrument company 1-800-428-7545), respectively. A non-parametric mediation analysis, controlling for sex, was conducted using IBMSPSS statistics v.245. Meditation between MVPA and FMS was shown through HRF but not PMC in early childhood and middle childhood. Results propose HRF influences a child's health trajectory earlier than PMC. Therefore facilitating environments and interventions that improve HRF through MVPA encompassing all FMS from early childhood may be crucial in promoting positive health trajectories.

7.3 Introduction

Globally, childhood obesity has been deemed a public health crisis (Karnik and Kanekar 2012). Within the UK one in five children enter mandatory primary education at 4-years-old overweight/obese and one in three children leave (ten-to-11-years-old) classified as overweight/obese (Public Health England 2016). The detrimental effects of childhood obesity and beneficial effects PA are well known (Kumar and Kelly 2017). Ensuring children follow a positive trajectory of health may be key in reducing obesity. Stodden et al. (2008) presented a conceptual model of the development of a healthy or unhealthy weight status. Four main mechanisms as influencers of the proposed health trajectories (Stodden et al. 2008): (i) PA levels (ii) actual FMS (iii) PMC and (iv) HRF. In the model, the direct relationship between PA and FMS is suggested to be mediated by PMC and HRF (Stodden et al. 2008). A ‘positive spiral of engagement’, where a child demonstrates greater ability to perform FMS, has a higher PMC and better HRF as well as engaging in more PA, result in a child being of a healthy weight. Conversely a ‘negative spiral of engagement’ may be seen, where the behaviours previously discussed are low resulting in the development of unhealthy weight/obesity. Understanding the mechanisms influencing a child’s health trajectory is important as childhood PA engagement levels and overweight/obesity tracks into adulthood (Kumar and Kelly 2017). This is particularly vital in children that are at a higher risk of following a ‘negative spiral of engagement’ such as those from deprived and ethnically diverse areas as shown in study one. Although the conceptual model by Stodden et al. (2008) has been widely cited/used to support the role of motor competence in children’s PA and weight status, a more recent review by Robinson et al. (2015) investigated extant literature examining the associations between these mechanisms. Robinson et al. (2015) concluded that the effect of motor competence/FMS on PA and weight status was supported but, there was a lack of empirical data exploring PMC and HRF as mediators.

Despite the assertions of Robinson et al. (2015), there is an emerging research base exploring PMC as a mediating mechanism. The work of Crane et al. (2015) highlighted perceived object-control competency did not mediate the relationship between object-control skills and MVPA in five-to-six-year-olds. However, to date, few other studies have examined this during early, middle or late childhood. Understanding if, and to what extent PMC mediates the effect of FMS on PA during childhood is important in developing effective intervention programmes. Barnett et al. (2011) explored the mediating mechanisms of PMC in adolescence (mean age 16.4 ± 0.6-years-old). A significant direct bi-directional relationship was reported between object-control skills and PA (self-report) that was also mediated through perceived sports competence (Barnett et al. 2011). PA engagement was shown to be directly associated with locomotor skills and mediated by perceived sports competence (Barnett et al. 2011), supporting the conceptual model (Stodden et al. 2008). Research relating to the role of PMC within the Stodden et al. (2008) model is therefore developing. However, the literature on this topic is lacking concerning the range of ages that have been examined as well as at-risk groups that demonstrate lower levels of mechanisms. There are also no studies that have examined PMC as a mediator of the FMS and PA relationship in British sample beyond the age of six-years-old (Robinson et al. 2015, Hall et al. 2018). Regarding the proposed mediating role of HRF within the conceptual model (Stodden et al. 2008), far fewer studies have explored this issue. In their review, Robinson et al. (2015) identified no literature that had investigated this topic. More recently Lima et al. (2017) reported longitudinal associations between moderate-to-vigorous PA (MVPA), vigorous PA (VPA), motor competence and body fatness mediated via VO_{2peak}, from six-to-13-years-old. Associations between MVPA, VPA and body fatness via motor competence were also shown with the greatest total association with body fatness was found in VO_{2peak} (Lima et al. 2017).

Literature supporting the mediation element of the conceptual model is evident and children in the latter years of childhood are yet to be examined. Crane et al. (2015) and Barnett et al. (2011) provided support for the model (Stodden et al. 2008), though both authors proposed PMC assessments used lacked alignment with FMS assessed. Furthermore, research conducted by Lima et al. (2017) did not assess PMC. The literature exploring the conceptual model for health trajectories in children (Stodden et al. 2008) is progressing and shows promise, though the mediating element is far less explored and the current literature exhibits areas of development. Understanding the relationships of the mechanisms influencing a child’s health trajectory could be pivotal for the current and future child population globally. Particularly in children living in deprived and ethnically diverse areas in the UK that are at greater risk of obesity, reduced PA levels and FMS acquisition/mastery as shown in study one.

The current study sought to firstly explore the direct associations between PA, FMS, PMC and HRF and; secondly, to evaluate PMC and HRF as mediating mechanisms between PA intensity and FMS during early childhood (four-to-five-years-old) and middle childhood (nine-to-ten-years-old). Recognising that object-control and locomotor skills are differentially associated with mechanisms within the conceptual model (Stodden et al. 2008, Robinson 2011), FMS were explored in their capacity as total FMS (all skills), object-control (strike, bounce, catch, throw and roll) and locomotor skills (run, gallop, hop, leap and jump).

7.4 Method

Sample selection

Please refer to section 5.2 and 6.4

Anthropometric data

Please refer to *section 5.3*

Process-oriented assessment of Fundamental Motor Skills

Please refer to *section 5.5.1*

Physical activity assessments

Accelerometers (ActiGraph wGT3X-BT, ActiGraph, USA) were used to collect PA data. The ActiGraph is deemed valid and reliable in its ability to collected PA data in four to ten-year-old children (Trost, McIver and Pate 2005). The ActiGraphs were worn consistently for seven days by participants on the dominant wrist, attaining weekday and weekend data (Trost, McIver and Pate 2005). Days one and seven were omitted from the study, classified as the days of fitting and removal, respectively (Van Cauwenberghe et al. 2011). Participants and parents were advised that the device must be worn at all times other than during activities where the device would be submerged for a long time (e.g. having a bath or swimming). An information sheet was provided to parents with all the necessary information.

Perceived Motor Competence assessment

Perceived ability of FMS was assessed using The Pictorial Scale of Perceived Movement Skills Competence for Young Children as guided by Barnett et al. (2015b); validated and deemed reliable in the paediatric population (Barnett et al. 2015a, Barnett et al. 2016). Scores for the perception of each skills ability ranged from one to four; one (*not too good*), two (*sort of good*), three (*pretty* *good*), four (*really good*). For the purpose of understanding within studies one and two, both two and three were described to participants as "sort of good". *Study One* and *Study Two* produced overall scores between 12 and 48 calculated from locomotor skill subtest (6 to 24) and object control skill subtest (6 to 24) skill. A possible overall score between 6 and 24 was calculated from locomotor (3 to 12) and object control skills (3 to 12) for study four.

Health-related fitness measures

Please refer to *section 5.6*

To provide one HRF measure a composite score was calculated (sprint + SLJ + hand grip) sprint speed being reversed recognising that lower scores on the sprint related to better fitness (Duncan et al. 2012).

Statistical analysis

Participants were excluded from data analysis if they exhibited developmental delays (e.g. sever special education needs, motor control/development delays), data was missing from any variable or, they or their parent/guardian no longer wished to participate. For PA data to be deemed valid a minimum of four whole days (>10 hours per-day) including at least one weekend day were required to be present (Janz, Witt and Mahoney 1995, Trost, McIver and Pate 2005, Tudor-Locke et al. 2015). The intensity levels of PA engagement were identified using wrist-worn cut-points set by Johansson et al. (2015) for participants in early childhood and those set by Crouter et al. (2015) for participants in middle childhood. A total of 48 participants (early childhood; 42 and middle childhood; six) were removed from the study.

To examine the relationships between PMC, HRF, FMS and average time spent in MVPA, means and SD's were calculated and a non-parametric mediation analysis was conducted (Preacher and Hayes 2008) using IBM SPSS Statistics software (v.24 IBM Corp Amork USA). Direct relationships between all four mechanisms, as well as the mediation of FMS and MVPA through PMC and HRF were assessed. The components of PMC and FMS were included within the models within their capacities as Total FMS, object control and locomotor skills (figure 7.1, figure 7.2 and figure 7.3, respectively). A significant mediation was established where confidence intervals (CI) lower and upper bounds did not pass through zero (Preacher and Hayes 2008). Due to the ethnicity and sex differences found in *Study One*, ethnicity and sex were controlled for within the analysis. Ethnicity was then removed as it was not a significant covariate.

7.5 Results

Descriptive data (Means, SD's) of PMC, FMS, HRF, and MVPA levels for children in early and middle childhood are shown in *Table 7.2.* A total of 128 participants (early childhood: *n*=51, 4.96±0.20 years-old; middle childhood *n*=77, 9.62±0.49 years-old) provided valid data sets and were included in the analysis. Independent T-Test's (early vs. middle childhood and males vs. females) highlighted significant differences across all variables between children in early and middle childhood with large effect sizes (*see table 7.2*). Sex differences across all variables were also shown where males outperformed females, except for PMC of locomotor skills and MVPA (*see table 7.2*).

Table 7.2. Descriptive statistics for participant demographic

		Early childhood	Middle childhood
	N	51	77
	Age	4.96 (0.20)	9.62 (0.49)
Perceived motor competence	Total FMS (12-48)*$^{(d=.99)}$	35.43 (4.37)	31.27 (4)$^{+}$
	Object-control (6-24)*$^{(d=.72)}$	17.76 (2.52)	15.87 (2.70)$^{+}$
	Locomotor (6-24)*$^{(d=.93)}$	17.67 (2.46)	15.40 (2.41)
Fundamental motor skills	Total FMS (0-80)*$^{(d=2.35)}$	46.24 (7.29)	62.64 (6.64)$^{+}$
	Object-control (0-40)*$^{(d=2.23)}$	20.10 (5.08)	31.06 (4.73)$^{+}$
	Locomotor (0-40)*$^{(d=1.52)}$	26.14 (4.05)	31.57 (3.03)$^{+}$
Moderate-to-vigorous physical activity average (minutes)*$^{(d=2.77)}$		154.08 (30.10)	252.86 (40.40)
Health-related fitness score*$^{(d=2.33)}$		-0.83 (0.40)	0.65 (0.83)$^{+}$

*Significant difference between developmental stages: $p<0.001$

$^{+}$Significant difference between genders within the developmental stage: $p<0.001$

7.5.1 Direct Associations

Non- parametric mediation analysis was conducted where both FMS (Total, locomotor and object control skills) and MVPA engagement were independent and outcome variables and, PMC and HRF acted as mediating mechanisms (*see Figures 7.1 to 7.3*). There were no direct relationships shown between PA and FMS across total, locomotor or object control skill during early or middle childhood (*Figure 7.1 to 7.3*).

A bi-directional association was found in middle childhood between FMS and PMC of object-control skills (β=.17, t(77-2)= 2.63, p= 0.01 and β=.35, t(77-4)= 1.99, p= 0.05*; figure 7.2*). A direct association was revealed where total FMS and locomotor skills were associated with PMC (β= 0.19, t(77-2)= 2.68, p=

0.009; *figure 7.1* and β= -.0036, *t*(51-1)= -0.038, *p*= 0.97; *figure 7.3*, respectively). Concerning children in early childhood, FMS and PMC were not associated and PMC was not associated with MVPA at either developmental stage.

Total FMS was bi-directly associated with HRF in early childhood (β= 0.59, t(51-1)= 2.64, *p*= 0.01 and β= 0.18, t(51-1)= 2.15, p= 0.04, respectively) and middle childhood (β= 0.06, *t*(77-2)= 3.64, p= 0*.0005 and* β=2.29, *t*(77-4) = 3.17, *p*= 0.002, respectively). Considering the subtest of object-control, a bi-directional association was revealed with HRF middle childhood (β=.09, *t*(77-2)= 4.00, *p*= 0.0001 and β= 1.96, *t*(77-4)= 4.01, *p*= 0.0001, respectively). Conversely, a unidirectional association was shown in early childhood where HRF was the outcome measure of object-control skills (β= 0.69, t(51-1)= 2.09, *p*= 0.04; *figure 7.2*) and locomotor skills (β= 0.84, t(51-1)= 2.02, *p*= 0.049; *figure 7.3*). Locomotor skills and HRF were not associated in middle childhood.

The association between HRF and MVPA engagement was bi-directional for children in early childhood including FMS subtests of object-control skills (β= 0.75, t(51-1)= 2.13, *p*= 0.04; β= .13, t(51-1)= 2.36, *p*= 0.02 and directly associated during middle childhood (β= 12.32, *t*(77-4)= 2.32, *p*= 0.02). This was also shown for children in middle childhood where total FMS was included in the model (β= 11.63, *t*(77-4)= 2.12, *p= 0.04*). However, a direct relationship was only shown in early childhood between MVPA and HRF engagement where total FMS as well as locomotor skills were included in the model (β= 0.13, *t*(51-1)= 2.36, *p*= 0.02 and β= 0.13, t(51-1)= 2.36, *p*= 0.02, respectively).

7.5.2 Mediation analysis

PMC did not mediate the relationship between MVPA and FMS in early or middle childhood. Mediation occurred between Total FMS and PA via HRF in early and middle childhood (β= 0.02; CI= 0.004 to 0.07 and β= 0.72; CI= 0.07 to 1.79). The relationships in early childhood between both object-control and locomotor skill, and MVPA was bi-directionally mediated by HRF (β= .52; CI= 0.03 to 1.38, β= 0.01; CI= 0.001 to 0.04 and β= 0.61; CI= 0.05 to 1.52, β= 0.1;

CI= 0.001 to 0.03) but not in middle childhood. The direct relationship between PA and object control skills was mediated through HRF (β =1.11; CI= 0.19 to 2.49).

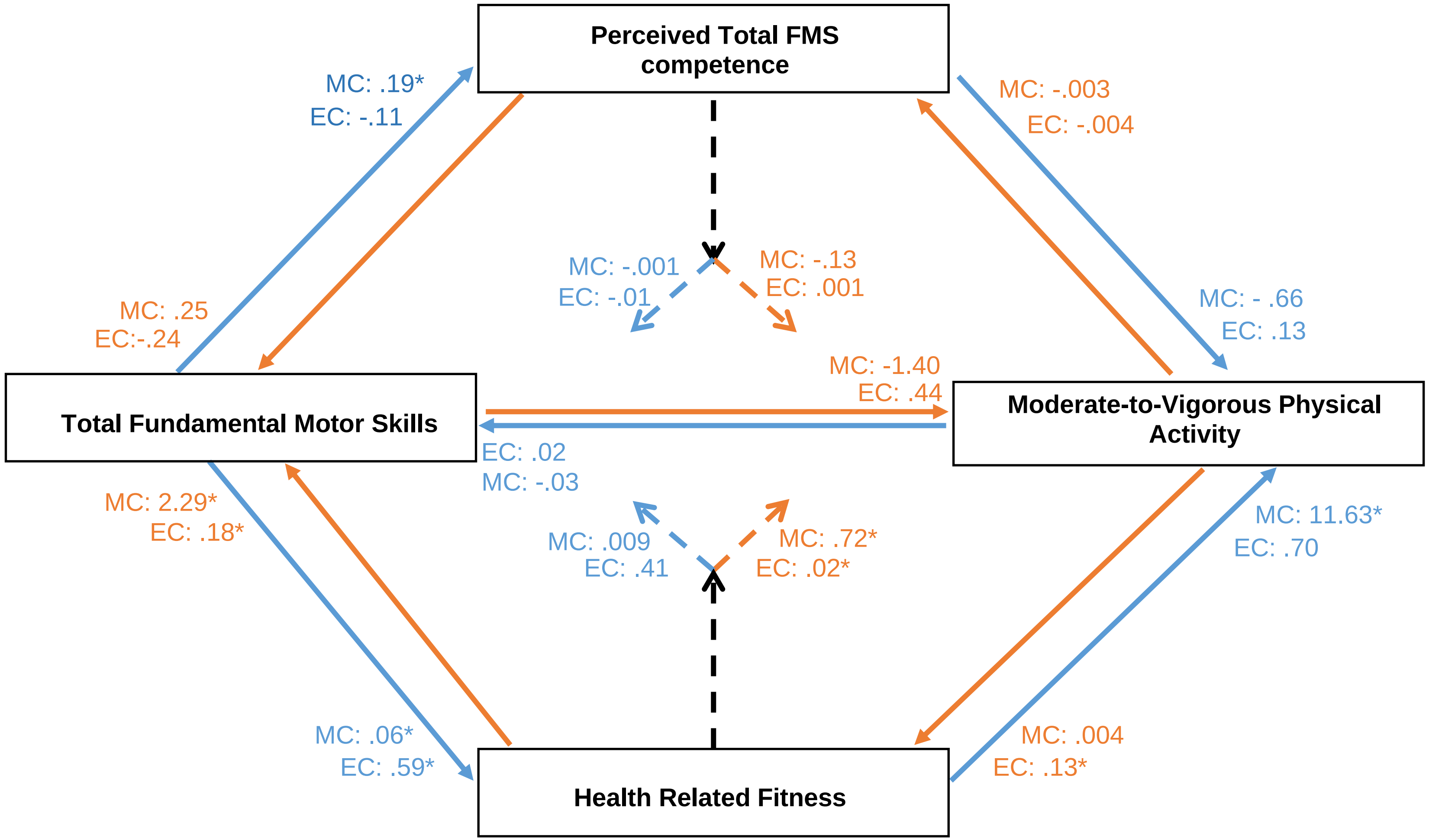


*Figure 7.1. Non-parametric mediation analysis: direct and indirect associations between total FMS (independent and outcome variable), PMC (mediator), HRF (mediator) and MVPA (outcome and independent variable) in middle childhood (MC) and early childhood (EC). (a) Solid orange and blue lines, and coefficients: direct associations between mechanisms, (b) Striated lines and coefficients: mediation of the direct relationship through PMC. * indicates a significant association between mechanisms P<0.05.*[2]

[2] The health-related fitness measure was calculated as a composite score of standing long jump + sprint speed (reversed) + handgrip

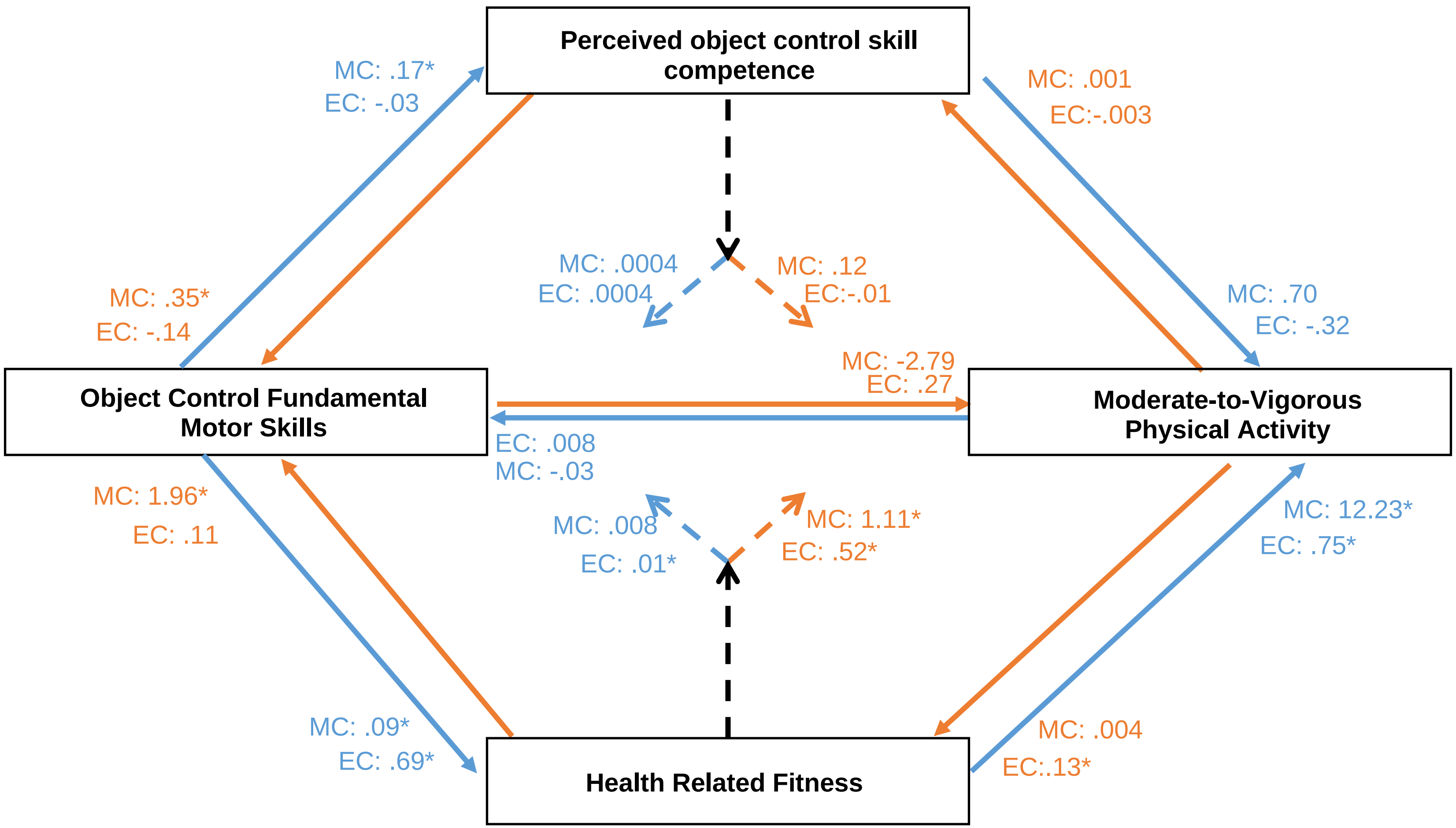


*Figure 7.2. Non-parametric mediation analysis: direct and indirect associations between object control FMS (independent and outcome variable), PMC (mediator), HRF (mediator) and MVPA (outcome and independent variable) in middle childhood (MC) and early childhood (EC). (a) Solid orange and blue lines and coefficients: direct associations between mechanisms, (b) Striated lines and coefficients: mediation of the direct relationship through PMC. * indicates a significant association between mechanisms P<0.05.*

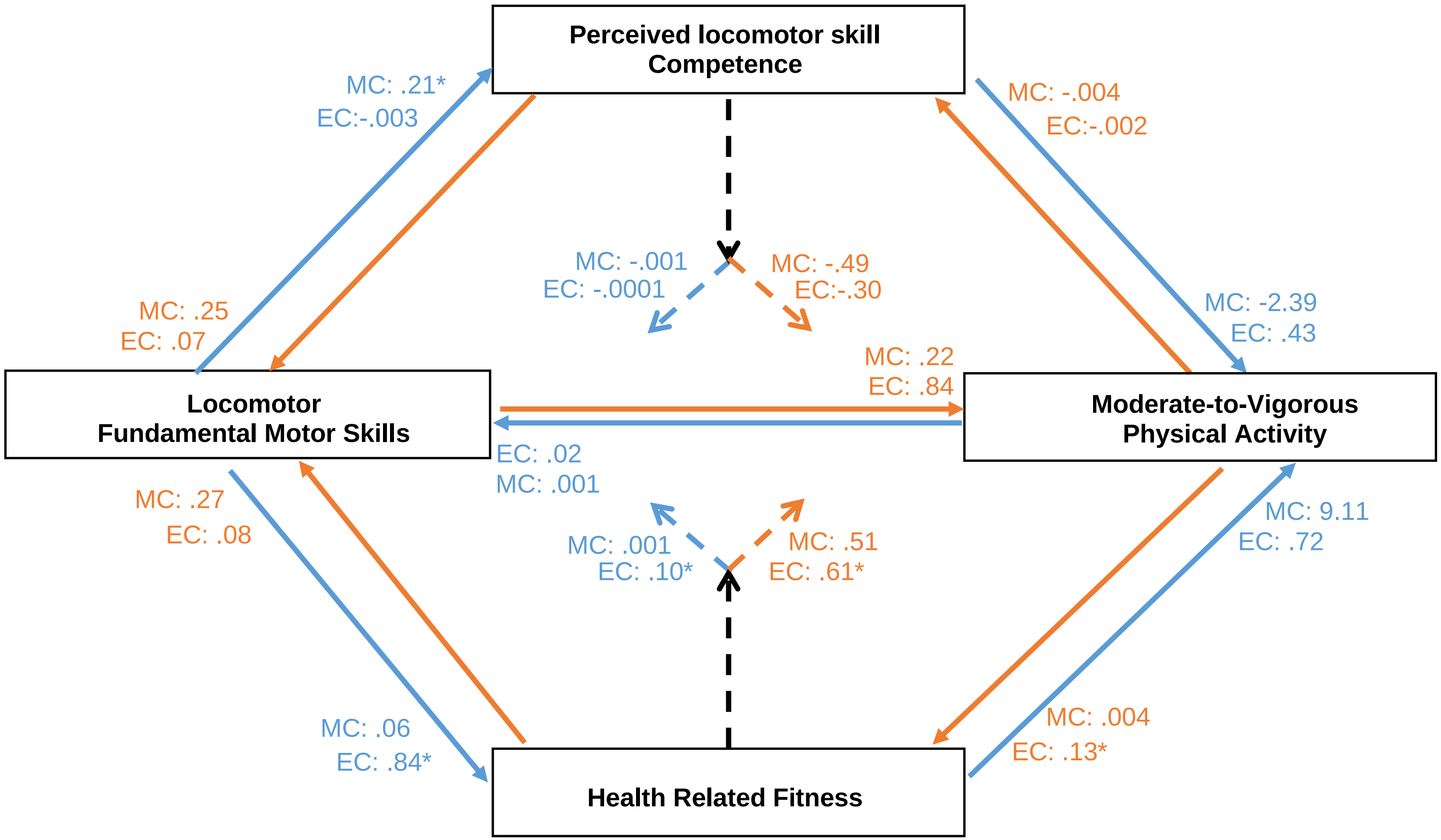


*Figure 7.3. Non-parametric mediation analysis: direct and indirect associations between locomotor FMS (independent and outcome variable), PMC (mediator), HRF (mediator) and MVPA (outcome and independent variable) in middle childhood (MC) and early childhood (EC). (a) Solid orange and blue lines and coefficients: direct associations between mechanisms, (b) Striated lines and coefficients: mediation of the direct relationship through PMC. * indicates a significant association between mechanisms P<0.05.*

7.6 Discussion

This study sought to explore the direct associations between PA, FMS, PMC and HRF as well as examine PMC and HRF as mediating mechanisms between MVPA and FMS during early and middle childhood in the UK. An empirical assessment of this entire theoretical model has not been conducted prior to this study within this specific demographic. The key novel findings from the present study are first that HRF accounted for significant variance in the models compared to PMC during early and middle childhood. Mediation through HRF occurred where total, as well as object-control FMS and their association with MVPA, were observed within the model in both directions, during early and middle childhood. Whereas locomotor skills were only mediated via HRF during early childhood. Mediation did not occur at either developmental stage through PMC. Additionally, there was no direct relationship between FMS and PA during either developmental stage.

In support of findings, a review showed strong positive associations are presented between motor competence and HRF, as measured by cardiorespiratory fitness (*r= .32 to .57*) and muscular strength/endurance (*r= .27 to .68*) during childhood and adolescence (Cattuzzo et al. 2014). The current study provides greater specificity of findings through FMS subtests and age in that, total and object control FMS were directly associated with HRF during middle and early childhood and locomotor skills were associated with HRF only during early childhood. These direct associations have partially been broadly attributed to PA engagement patterns; participating in PA provides opportunities for proficiency and various components of HRF to develop as skills require physical effort as well as neuromuscular coordination/control (Cattuzzo et al. 2014). This assertion reflects proposals highlighting the need for force production, movement patterns and cognitive processing to perform FMS (Lloyd and Oliver 2012), as well as the consensus that skill proficiency is required for engagement in PA and PA engagement is necessary for skills to be developed as it provides opportunities for skills to be practiced and reinforced (Robinson et al. 2015).

Along with the direct associations between HRF and FMS proficiency shown within the sample, HRF was shown as a positive mediator between FMS and PA. As this was the first study to empirically assess the entire model, and HRF as a mediator, comparison to other literature is limited. This finding, however, expands explorations of direct association; It also supports the role of HRF proposed within the conceptual model (Stodden et al. 2008) and provides a greater understanding of the mediating properties. HRF can be said to partially explain the association between FMS (total and object-control) and MVPA in both directions from as early as four-years-old and between nine and ten-years-old. Showing that HRF may be an important mechanism throughout childhood for both the quality of movement (object-control skills) demonstrated as well as the amount of PA engaged in, subsequently influencing a child's health trajectory. However, where locomotor skills were concerned, HRF partially explained the bi-directional association with MVPA only during early childhood. The importance of locomotor skill in the promotion of an active lifestyle during early childhood has been suggested (Williams et al. 2008, Crane et al. 2015). The current study supports and further develops this; a smaller coefficient was shown where locomotor skill was the outcome measure. Therefore, it may be that though the mediation is bi-directional, MVPA engagement may be more influential than a child ability to perform locomotor skills during early childhood. This does not seem to be apparent by the time a child reaches the ages of nine-to-ten-years-old, at which point object-control skills may be of greater influence and have been observed to be positively associated with time spent in MVPA and organised PA during adolescents (Barnett et al. 2009). Further insight into the conceptual model from five-to-nine-years-old would broaden this understanding and the potential transitioning of HRF as a mediator across a child's developmental time.

Research has shown positive associations between FMS proficiency and PMC of object-control skills in four-to-eight-year-old children (Barnett, Ridgers and Salmon 2015). However, ages were not separately assessed by year and locomotor skills were not included as in the current study. A limitation in cognitive ability creates a challenge for young children when distinguishing between 'ideal' and 'reality' terms of competence (Harter 2015). As cognition develops in middle childhood the perceived exaggeration becomes more accurate (Robinson et al. 2015). Thus, the development of cognition may in part explain the association between FMS and PMC shown in middle childhood and not early childhood. Additionally, the varying strength between sub-tests may propose that locomotor skills require further advancement of perceptual accuracy than object-control skills.

PMC of children in early childhood and middle childhood of the current study did not mediate the direct relationship between MVPA and FMS. Early childhood observations align with the literature (Crane et al. 2015) and potentially relate to the previous discussion of PMC limitations in early childhood. (Harter 2015) The lack of mediation found during middle childhood presents a novel finding. Barnett et al. (2011) reported PMC as a mediator between FMS subtests and MVPA in adolescence. Thus, the current study suggests that the mediating capacity of PMC may initiate at a later stage in childhood/early adolescence. Further exploration during the latter stages of middle childhood, late childhood and adolescence (ten-to16-years-old) would provide greater insight.

The current study presented no direct relationship between FMS and MVPA during early or middle childhood. This finding contradicts general proposals within the theoretical model (Stodden et al. 2008) as well as a supporting review (Lubans et al. 2010), which was further substantiated stating that the relationship strengthens from early to late childhood (Logan et al. 2015). It is important to note that a significant mediation is possible where no direct relationship occurs as although the independent and dependent variable may not be directly associated, the associations between these two variables and the mediator are considered; the *a-path* is multiplied by the *b-path* which in this instance is shown in *Figure 7.1* as Total FMS/MVPA and HRF/Perceived (*a-path*) and, HRF/Perceived and MVPA/Total FMS (*b-path*; Hayes 2017: pg. 116). Overall mastery achievement of FMS was low, children during middle childhood did not reach the levels of proficiency as expected within this age-group (Stodden et al, 2008), although children from deprived and ethnically diverse areas have been shown to demonstrate lower skills proficiency (Morley et al. 2015, Eyre, Walker and Duncan 2018). Where FMS are expected to be low, as in early childhood the association between FMS and PA is suggested to be weaker (Stodden et al. 2008, Logan et al. 2015). As children in middle childhood also showed low levels of FMS mastery achievement, this may have contributed to the lack of direct association between FMS (total, object control and locomotor skills) and MVPA engagement. Furthermore, the lack of direct association, along with the aforementioned findings regarding HRF and PMC as mediators, suggests that the theoretical model may not emerge within this sample as initially proposed and that it may be context-specific. As this was the first empirical assessment of the theoretical model within this population further investigation is required.

7.7 Strengths and limitations

Strengths of the study are found firstly; in that, it was the first to provide experimental data for the assessment of the entire conceptual model proposed by Stodden et al (2008). A valid and reliable objective assessment method was used to identify PA engagement levels of children in both early and middle childhood using accelerometers (Trost, McIver and Pate 2005). Additionally, the assessment of HRF was composed of three components that were all measured objectively through valid and reliable protocols (Roberts et al. 2011, Tambalis et al. 2013) and has previously also been combined as a composite score in children (Duncan et al. 2012). The measure of HRF in the current study included important components of strength, lower-limb power and speed. These components are particularly important as FMS require a combination of appropriate force production, the correct movement patterns and cognitive processing (Lloyd and Oliver 2012). The component of HRF is, however, often in reference to cardiovascular fitness (Stodden et al. 2008). Both cardiovascular fitness and the HRF components measured in the current study have shown strong positive associations with proficiency (Cattuzzo et al. 2016); comparisons between cardiovascular fitness, strength, lower-limb power and speed components, and their relation to FMS proficiency is limited. Incorporating cardiovascular fitness measures may have provided greater insight into the efficiency of aerobic processes to produce FMS movements, however, considering the important components related to FMS previously mentioned, the measure of HRF used may align more accurately than cardiovascular fitness. Additionally, the 20m shuttle run test has been identified as the most appropriate method to examine cardiovascular fitness in children (Batista et al. 2017). Due to some of the participants being between the ages of four-to-five-years old as well as the time and space available for testing this method would not have been pragmatic; testing was conducted during PE lessons, limiting testing time and in school halls which would not accommodate the 20m distance.

The TGMD-2 is a widely used FMS-AT in children, presenting with good levels of reliability and validity (*see section 4.11*). The Pictorial Scale of Perceived Movement Skills Competence for Young Children is founded upon the skills within the TGMD-2, thus enabling direct alignment of actual and perceived FMS assessments within the current study. The assessment of the conceptual model was conducted in a unique sample limiting the ability to generalise the findings. However, valuable experimental data is provided concerning influential mechanisms within a unique group that is proposed to be at greater risk of '*negative spiral of* engagement' (Stodden et al. 2008).

7.8 Conclusion and practical application

The current study makes a novel contribution to the literature by adding to the Stodden conceptual model (Stodden et al. 2008). This is the first study to assess the model in its entirety; considering both mechanisms of PMC and HRF concerning PA and FMS. Being aware of the difference in associations resulting from the HRF mediation, where locomotor skill association lacked at MC, distinguish between types of PA, namely play type behaviours and organised sports activity engagement may be key in providing further understanding.

The development of FMS is influenced more by a child's HRF than their PMC. Focusing on improving HRF measures may be key in reducing the low levels of FMS proficiency shown in children during early and middle childhood from deprived and ethnically diverse backgrounds. Furthermore, where possible interventions should aim to be implemented during early childhood although, as the influence of HRF is also shown during middle childhood there is scope for interventions to also be implemented within this age-group to reduce the deficits in FMS mastery achievement, as shown in *Study One*.

7.9 Thesis Map 7.1

Table 7.3. Thesis map 7.1

STUDY	AIMS	OBJECTIVES
Study Two: *"The mediating roles of perceived motor competence and health-related fitness for children's physical activity."*	To examine factors affecting motor competency and moderate to vigorous physical activity engagement. Exploring and objective context for study one.	• To examine FMS, MVPA, PMC and HRF during early and middle childhood. • To assess the indirect associations between FMS and MVPA bi-directionally through PMC and HRF during early and middle childhood.

KEY FINDINGS:

- PMC did not mediate the relationship between FMS and MVPA in either direction.
- The relationship between FMS and MVPA was mediated through HRF during early and middle childhood

8.0 STUDY THREE: FUNDAMENTAL MOVEMENT SKILLS AND PHYSICAL ACTIVITY OF PRIMARY SCHOOL CHILDREN IN A DEPRIVED AND ETHNICALLY DIVERSE AREA IN ENGLAND: A PRIMARY SCHOOL TEACHERS' PERSPECTIVE

8.1 Thesis Map

Table 1. Thesis map 8.0

STUDY	AIMS	OBJECTIVES
Study One: *"Fundamental motor skills of children in deprived areas of England: a focus on age, gender and ethnicity."*	To asses FMS mastery of males and females' children schooling in deprived ethnically diverse areas in England.	• To examine process and product FMS of males and females in early and middle childhood. • To compare process and product measures of FMS in males and females as well as Black, White and Asian ethnicities between and within children in early and middle childhood.
Study Two: *"The mediating roles of perceived motor competence and health-related fitness for children's physical activity."*	To examine factors affecting motor competency and moderate to vigorous physical activity engagement. Exploring and objective context for study one.	• To examine FMS, MVPA, PMC and HRF during early and middle childhood. • To assess the indirect associations between FMS and MVPA bi-directionally through PMC and HRF during early and middle childhood.
Study Three: *"Barriers and facilitators of FMS development, pa engagement and PE: a primary school teacher's perspective."*	**To explore a Teachers perspective of FMS development, PA engagement and PE curriculum in England. To provide additional context of study one and inform study four.**	• **To identify the perceptions and suggestions of the following topic of teaching staff in schools located in deprived ethnically diverse areas:** ○ **PA and PE in England** ○ **Barriers and facilitators of PA and motor development** ○ **PE within the curriculum and the delivery of PE** ○ **Training for PE** ○ **Incorporating PE specialists in the delivery of PE**

Study Four: *"The effect of integrative neuro muscular training on fundamental motor skills and health-related fitness in nine-to-ten-year-old"*	To assess the effect of a 6-week INT programmed on FMS and HRF measures in nine-to-ten-year-old males and females at pre-, post and post-6-week intervention period.	• To asses FMS and HRF measures at baseline • To implement a 6-week INT programme • To assess FMS and HRF measures immediately post the intervention programme To assess FMS and HRF measures post 6-weeks intervention

8.2 Abstract

Children in deprived and ethnically diverse areas in England are not achieving the UK recommended PA guidelines for health or FMS mastery as expected. Evidence suggests that primary school environments are pivotal in PA engagement and FMS development. This study sought to build on previous findings from preschools teachers and parents of primary school children; providing novel insight into the barriers and facilitators of PA and FMS perceived by primary school teachers. Semi-structured focus groups of two-to-four participants were conducted, in two primary schools in Coventry. Data were transcribed verbatim, anonymised and examined using thematic analysis identifying codes and themes. PE and PA were perceived as beneficial although some teachers lacked scientific underpinning-knowledge. The primary PA and FMS barriers perceived by teachers were unsafe local areas, parents, lack of PA experience/exposure and a crowded curriculum; often linking to ethnic diversity and deprivation. Perceived facilitators included the school environment, teachers and community structures. PE was seen to lack priority compared to English and maths with minimal initial or subsequent teacher-training. Mixed views of PE specialists were shown. Benefits included consistent PE/extra-curricular activity provision and reducing teacher's workload with limitations centred on PE becoming a specialist subject, compromised curriculum achievement and teachers being de-skilled. This study provides novel insight into the importance of school environments in improving PA engagement and FMS development of children living in deprived and ethnically diverse areas. Interventions should aim to integrate into the curriculum structure causing minimal disruption within sustainable models; incorporating teacher-training to facilitate continuous delivery without researchers/specialists.

8.3 Introduction

The UK PA guidelines for health recommend that school-aged children engage in 60+ minutes of MVPA per day as well as activities that strengthen muscle and bone at least three-days per-week (Chief Medical Officer, 2011). A large percentage of children between the ages of four-to-11-years-old are not achieving these guidelines (Townsend et al. 2015, World Health Organisation

2017); with England achieving an overall C- rating as identified by England's 2018 PA report card which summarises PA related health statistics (Standage et al. 2018). Due to the levels of PA, many children are not active enough to experience the physiological, psychological and social health benefits from engagement that improve health status and track into adulthood (Janssen and LeBlanc 2010, Vina et al. 2012, Foulds et al. 2014). Physical activity is a multi-dimensional and complex behaviour which is influenced by physiological, psychological, social, environmental and demographic factors (Bauman et al., 2002).

For children to engage in PA they require the ability to carry out FMS (e.g. running, jumping, throwing, catching) incorporated within it (Robinson et al., 2015). Primary school is the first opportunity provided to every child in England to develop their FMS through the PE curriculum delivered by teaching staff (DfE 2014). Furthermore, the PE curriculum in England, implemented since September 2014, focuses towards motor skill development from acquisition in early years (four-to-five-year-olds) to mastery and application (six-to-11-years-old) (DfE, 2014; Foster and Adcock, 2016). However, FMS proficiency in England since the implementation of the new curriculum is low (Foulkes et al. 2015) and expected FMS mastery attainment is lacking in children living in deprived and ethnically diverse areas in England as shown in study one. Additionally, many children within these areas are also not meeting the recommended PA guidelines for health (Eyre et al., 2015). It is therefore important to understand factors contributing to the current prevalence of FMS development and PA engagement.

The barriers to PA of children living in low socioeconomic areas that are ethnically diverse have been explored from the perspectives of parents. Engagement in PA was beneficial although parents lack knowledge (Eyre et al. 2014) which was also seen as a hindrance to a child's PA engagement (Trigwell et al. 2015). Further to this, parent lifestyles (e.g. work commitments, other responsibilities) were also seen to negatively impact a child's ability to engage in PA (Trigwell et al., 2015). Multiple environmental barriers were identified within the local area including a lack of facilities and safety relating to heavy traffic, strangers and unsafe neighbours/neighbourhoods (Eyre et al. 2014, Trigwell et al. 2015). Although home and environmental barriers were present, as children spend the majority of their time in school, it was seen as an important structure in PA engagement of children (Eyre et al. 2014). Parents also perceived that schools are primarily responsible for PA levels of children (Trigwell et al., 2015). However, in-depth exploration of the school environment as perceived by teachers is limited as they were not included in either study (Eyre et al. 2014, Trigwell et al. 2015).

Perceptions from classroom teachers have only been explored at the preschool level (two-to-four-years-old), where parents were also included, exhibiting some similarity to previous findings (Roscoe, James and Duncan 2017). Perceptions from the head and deputy headteachers, as well as PE co-ordinators, have also been explored but only concerning school-based PA (Domville et al. 2018). The main barriers to a child's PA opportunities perceived included parents' busy lifestyles, lack of income and activities being expensive (Roscoe, James and Duncan 2017). The lifestyle barrier perceived by parents is supported (Trigwell et al. 2015). School-related barriers were also highlighted by classroom teachers, head and deputy headteachers, as well as PE co-ordinators. These included limited outdoor space, obstacles within indoor spaces (e.g. chairs) as well as health and safety caution of specific staff (Roscoe, James and Duncan 2017, Domville et al. 2018). Additionally, interpersonal and intrapersonal factors have been perceived to create barriers to school-based PA; such as opportunities to promote PA being reduced by significant others (e.g. parents), relationships between teachers and specialists/coaches being poor, as well as a lack of teacher training specific to PE and the interest teachers have in sports and PA varying (Domville et al. 2018). The perceived PA barriers encountered by children in England include multiple factors internal and external to the school environment.

Current findings provide valuable insight although there is a greater focus on PA with limited inclusion of FMS. Considering the specific FMS aims with the PE curriculum (DfE 2014) and the current lack of FMS mastery attainment of skills required for PA engagement (Adeyemi-Walker et al. 2018) the exploration of both PA and FMS is pivotal. Furthermore, literature has not focused on the perception of class teachers beyond preschool (Roscoe, James and Duncan 2017, Domville et al. 2018). Primary school curriculum aims to become more formally structured following preschool including teaching, learning and assessments (DfE 2014, 2017). It is within these years that FMS are expected to be acquired and later mastered but are currently low in children living in deprived and ethnically diverse areas (four-to-five-years-old and nine-to-ten-years-old (Adeyemi-Walker et al. 2018). Furthermore, children within this demographic engage in the majority of their PA at school, yet guidelines are not being met sufficiently (Eyre et al. 2015, Hesketh, Griffin and Sluijs 2015). Understanding the specific barriers and facilitators contributing to the low levels of FMS proficiency and PA engagement of these children will develop and tailor current findings of these critical stages in their development that are seemingly inhibited, informing better practice.

This study sought to identify the barriers and facilitators to FMS development, PA engagement and PE perceived by teaching staff of primary schools located in a deprived and ethnically diverse area in England. The study was also designed to provide insight into the practical reality of these three areas within primary schools for the first time, as well as to inform the design and execution of future FMS and PA intervention studies implemented within the primary school environment.

8.4 Method

Study design

A qualitative focus group design was used in study three to identify the facilitators and barriers of FMS development and PA engagement in primary school children from a Teachers perspective. Focus groups took place consisting of no more than four members of employed primary school teaching staff and separated by the school, year group, and occupation (Teacher or Teaching Assistant) to maintain homogeneity. The conduct and reporting of data were carried out in line with The Consolidated criteria for reporting qualitative research (COREQ; full details can be found in Tong, Sainsbury and Craig 2007).

Sample selection

Following Coventry University institutional ethics approval (Ref: P45655), informed consent was provided by teaching staff involved in the planning and/or delivery of the primary school curriculum including PE in England (reception *n*=eight, all female; year 5 *n*=six, five female), who took part in the study. All participants were recruited using convenience sampling from local primary schools situated in the most deprived electoral wards in Coventry (Insight 2015a, Insight 2015b). Focus groups included between two-to-four participants and maintained homogeneity; separated by school, year group (reception or year 5), occupation (Teacher or Teaching assistant).

The method of focus groups to attain the desired information was more suitable for the current study; literature has expressed focus groups to create a more natural environment for discussion to take place in (Wilkinson 2004). Furthermore, focus groups encouraged participants to engage in conversation, enabling them to add and respond to comments made by other participants; where they may also be prompted by one-and-others comments (Wilkinson 2004).

The five focus groups were facilitated by the Principle investigator facilitated five focus groups (Guest, Namey and McKenna 2017) for study three (*see section 8.0*). Focus groups were semi-structured and conducted to collect data in schools and held at the time most convenient for participants (lunchtime or after school), lasting between 45-55 minutes. Focus group discussions were guided by five main topic areas; (1) perceptions of PA, (2) perceived barriers and facilitators of PA engagement and motor development internal and external to the school environment, (3) Barriers to the planning and delivery of PE, (4) Teacher training, (5) Benefits and limitations of PE specialists as guided by previous findings (Harris, Cale and Musson 2012, Eyre et al. 2014, Trigwell et al. 2015, Roscoe, James and Duncan 2017). Topic areas and the questions included within were based on the previous qualitative and quantitative findings discussed. The trustworthiness of qualitative data is an important factor that consists of four components of credibility, transferability; dependability and conformability were deliberated as guided by Lincoln and Guba (Cohen and

Crabtree 2006, Lincoln and Guba 1985). To improve the credibility and transferability of findings within these topic areas, all participants were required to be classroom-based staff, working directly with the children in reception or year 5, and engage in the delivery of the primary school curriculum (Cohen and Crabtree 2006, Lincoln and Guba 1985). Considering the dependability of the study the method was informed and guided by previous research (Cohen and Crabtree 2006, Lincoln and Guba 1985) as well as analyst triangulation being conducted which will be described later (Cohen and Crabtree 2006, Patton 1999). The main questions within each topic were open-ended and followed by several possible questions, used to probe participants, thus increasing the depth of discussion. Probing was also conducted in response to participant's responses to facilitate greater conformability of the data (Cohen and Crabtree 2006, Lincoln and Guba 1985). Data was recorded using a Dictaphone (Olympus DS-2400, digital voice recorder, China) as well as making written notes where necessary.

Data analysis

Data from the focus groups were transcribed verbatim and anonymised using 'Fg' [NUMBER] to indicate the focus group, '/R or 5' to indicate the year group of the participant, followed by 'P[NUMBER]' to indicate the participant within the focus group (e.g. Fg2.1/R, P1). Thematic analysis was conducted as described by Braun and Clarke (2006) where initial codes were identified and subsequently organised into themes and sub-themes; which were reviewed and classified. Providing a broad flexible approach to the analysis of the data collected to produce an enriched and detailed account of findings (Braun and Clarke 2006). Analyst triangulation was conducted to increase quality and credibility of findings (Cohen and Crabtree 2006, Patton 1999) using a second independent analyst conducted a thematic analysis which was then compared with the primary researcher; assessing potential selective perception and blind interpretive bias (Cohen and Crabtree 2006, Patton 1999).

8.5 Results and discussion

This is the first study that sought to investigate the barriers and facilitators to PA engagement, FMS development and PE delivery and planning, perceived by primary school teachers in deprived and ethnically diverse areas in England;

presenting novel data. Teachers perceived PE and PA as beneficial although some lacked a depth of scientific underpinning-knowledge. The primary PA and FMS development barriers were unsafe local areas, parents, lack of PA experience/exposure and a crowded curriculum; often linking to ethnic diversity and deprivation. Facilitators included the school environment, teachers and community structures. PE lacked priority within the curriculum compared to English, maths and science, with minimal initial PE training or continued professional development (CPD); although teachers were willing to complete training, providing key recommendations. Mixed views of PE specialists were shown. Benefits included consistent PE/extra-curricular activity provision and reducing teacher's workload with limitations centred on PE becoming a specialist subject, compromised curriculum achievement and teachers being de-skilled.

8.5.1 *Teacher's perceptions of PA and PE*

Engagement in PA was perceived as advantageous for children; physically, psychologically, socially and for their future engagement. The majority of the benefits identified related to children having an improved ability to move with greater skill; improved agility, increased subsequent PA engagement and reduced injury risk. It should be noted that some often agreed with others' comments, with minimal explicit references relating to the physiological and biological benefits (e.g. cardiovascular disease, blood pressure, obesity risk (Warburton, Nicol and Bredin 2006). Thus, although teachers perceive PA and PE as beneficial, in-depth knowledge and understanding of these benefits may be limited in this sample.

Additionally, psychological benefits were also identified and associated with improvements in '*mental health*' and '*well-being*'. The minority provided explicit ideas with the majority agreeing with statements. Where specific examples were provided, a focus was drawn to the need for year 5 children to *'run around…especially with so much pressure in the classroom'*. This indicates that the primary school environment at this stage may be quite demanding and PA is used as means of stress release. The association between PA and mental health is complex (Crone, Smith and Gough 2006) however PA is supported as a natural means for improved mental health including stress relief (Tsatsoulis et al. 2006, Hegberg and Tone 2015).

Interestingly some teachers found that children were '*more focused [in the classroom]*' after engaging in PA. Enhanced classroom concentration levels following the 'Daily Mile' PA initiative have also been perceived by teachers in other parts of the UK (Malden and Doi 2019). Conversely, one reception teacher found that some children that were more physically active outside did not concentrate as much in academic subjects. A review of 137 studies conducted by Donnelly *et al.* (2016) supports the benefit of PA engagement to improved cognitive function in children as shown in school and laboratory-based studies. However, when focusing on concentration specifically, the limited literature presented equivocal findings. Further understanding may be gained through the cognitive demands of the PA engaged in. Schmidt, Bensing and Kamer (2016) observed school-based PA breaks (~10 minutes) with greater cognitive demand significantly improved the attention of children and enhanced processing speed. Thus, the differing concentration described by teachers in the current study may be linked to the cognitive demands during PA engagement.

Teachers also related the physical and psychological benefits of PA with PE, presenting a more holistic view. PE was perceived to be just as important as '*English and maths*', having the ability to impact children throughout their lives. However, teachers identified PE was not a priority in the curriculum at a delivery and policy level, and that some teachers lacked the confidence to teach PE primarily due to a lack of training and experience, which will be discussed further later. As a result, the provision of one teacher-led PE lesson per week is often missed and *'passed around'* by teachers who are not confident to deliver them.

8.5.2 *Barriers and facilitators to PA and motor development/competency perceived by teachers.*

Engagement in PA and motor development/competency of children were perceived by teachers to have a greater number of barriers than facilitators. Barriers identified were environmental (safety of the local area), parents, lack of PA experience/exposure and a crowded curriculum.

8.5.2.1 *Safety in the local area*

A general lack of safety within the area was perceived to limit PA engagement. Issues such as the use and remnants (i.e. *'syringes'*) of drugs and alcohol consumption throughout the day, particularly within the parks which were said to be *'too small', 'not clean*' and often *'vandalised'* were discussed. Therefore, parks were not seen as safe places for children to play in, reducing their PA opportunities. Teachers also indicated that local people contributed to the lack of safety, namely '*prostitutes*' who are often still out when the school opens in the mornings. In addition to this, roads are *'very busy'* with drivers who *'are not safe'.* This indicated that designated play areas and the local area itself were not a safe place for children.

The same perception of safety, based on similar components, has been previously identified by parents living in the same areas as the schools in the current study (Eyre et al. 2014)*.* As a result, parents would not allow their children to play in these environments (Allender, Cowburn and Foster 2006, Eyre et al. 2014). A review by Allender and Steven (2006) further supported this, where PA engagement was encouraged and supported less in environments that parents perceived as unsafe. Opportunities for PA engagement are therefore reduced; solidifying teachers' perceptions of the lack of safety as a barrier to PA engagement of children in their schools. A systematic review and meta-analysis observed objectively measured PA (An et al. 2017). An association was identified between children living in unsafe residential neighbourhoods and reduced PA engagement (An et al. 2017). However, evidence was limited to two studies and the association was described as 'modest' with the reduction in PA being 0.13 (95% CI = 0.06, 0.19) hours/week (An et al. 2017). The qualitative data therefore loosely supports the qualitative views of unsafe neighbourhoods. Further objectively measured PA in areas that are perceived as 'unsafe' (e.g. road traffic accidents, substance misuse) would provide greater insight into the current findings.

8.5.2.2 *Parents*

The second main barrier highlighted was parents; relating to cultural, social and economic elements. Teachers perceived that some parents place little importance/value on the PA engagement, which was exhibited in parents not engaging in PA and a few children engaging in PA outside of school. Direct perceptions from parents within similar locations, however, expressed that they perceived PA engagement as beneficial but felt it the responsibility of schools to ensure their children are active (Eyre et al. 2014, Trigwell et al. 2015). The perceptions of teachers in relation to parents seem to be based on their actions but may not be a true interpretation of parent's beliefs. Irrespective of this, the consideration Teachers have concerning parent encouragement/engagement and child engagement is supported. Where parents have provided encouragement to engage in exercise, adolescence have been shown to engage in PA over a significantly greater amount of days during the week (King et al. 2008). Moreover, engagement in PA by daughters has been shown to benefit from the meaningful engagement of their fathers (Morgan et al. 2018). Thus, if there is a lack of encouragement from parents, limited engagement outside of school may in-part be explained even if parents do perceive PA as important/beneficial. This needs to be examined more closely and to gain a true understanding of parents perceptions of PA it may be best to include parents in future studies.

This was further explored as teachers discussed the cultural backgrounds of the children. Sport and PA were not *'the done thing'* or integrated into day-to-day living within some cultures, namely Asian, North African and Czech, therefore PA may not be prioritised. Conversely, parents of children in England from Asian Bangladeshi, Black African, Black Somali, Chinese, White British and Yemeni backgrounds indicated that they valued PA (Trigwell et al. 2015). Though, in support of the current study they identified that academic achievement was prioritised over PA (Asian Bangladeshi, Chinese, Yemeni) as well as PA lacking cultural appropriateness, particularly for Muslim girls (Asian Bangladeshi, Black Somali, Yemeni; Trigwell et al. 2015).

Teachers simultaneously observed prejudices between different cultural groups within the area, causing a divide in the community. This was partially attributed to conflict, fear and lack of cultural integration resulting in children not being allowed to play outside. Considering the importance of parental support and encouragement in PA engagement of children (Allender, Cowburn and Foster 2006, Tate et al. 2015), this cultural element may provide further insight to the reduced PA engagement of children in deprived and ethnically diverse areas, however, it is challenging to definitively identify the main contributor (cultural norms vs. deprivation).

Additionally, teachers indicated that many homes were of low income, reducing the financial provision for children to attend sports clubs. The lack of household income can be expected as the schools within the study are located in one of the most deprived wards in Coventry, where 53% of children are classified as living in poverty (Valadez-Martinez and Hirsch 2018); classification was determined by household income >60%. It would be interesting to explore the cost of these activities between and within areas of low to high deprivation while considering measures including household income, although it is outside of the remit of this paper. Teachers also expressed that the majority of children in their schools were from big families with a '*high number of single parents..'* or where one parent was '…*always at work…'* creating a challenge to parents' ability to take their children to sporting activities.

> *'…imagine getting all of those ready to take your child to a club and then having to go back home and then get them all ready again to take them back out...there's not many that aren't in a big family.*' [Fg 5.2/5, P3]

Though the opportunities may be present, it was suggested that it might not be practical/easy for parents to take their children to activities. Overall, teachers propose that parents do not have the time to take their children to activities due to work commitments and family size. Furthermore, money may not be available for activities due to limited household income as well as the lack of importance placed on PA resulting in finances being directed elsewhere. Further investigation into this novel finding would provide a greater understanding of this concept.

8.5.2.3 Physical activity experience and exposure

The third main barrier was children having a lack of experience/exposure to PA engagement outside of school (e.g. not attending sports/activity clubs or local parks). This barrier was also associated with parents as they provide '…children [with] opportunities'. 'If they don't take them places, show and model things then they [children] don't know.' as well as practices at home. For example, parents dressing younger children because it is 'easier' and quicker. Children's ability to access and opportunities for PA engagement are therefore challenged. The impact that parents can potentially have on a child's PA engagement was also indicated in previous work (Domville et al. 2018). Participants also proposed that a parent being inactive can negatively impact the level of their child's PA engagement as parents provide PA opportunities which may be limited if they (parents) are not active themselves (Domville et al. 2018). Considering the barriers highlighted with parents (i.e. area safety), the lack of PA experience/exposure outside of school can partially be understood. Limited opportunities for children to engage in PA and therefore gain the necessary teaching and practice required for FMS development (Logan et al. 2012) in-part explain the reduced levels of PA engagement (Eyre et al. 2014) and FMS proficiency (Adeyemi-Walker et al. 2018).

Teachers also said that within homes parents often provide children with technologies to occupy them, which again was related to the lack of safety in the area. Children in lower-income households, much like those attending the schools in the current study, have been found to have greater access to technology and engage in increased amounts of sedentary behaviours (Tandon et al. 2012). Increased screen time and video game use by children has also been significantly associated with greater time spent in sedentary PA as well as reduced levels of cardiorespiratory fitness (Carson et al. 2016). In this instance, it would seem that the increased technological access is in-part due to parents perceiving the local environment as unsafe and the lack of priority placed on PA. The perceived barrier of children lacking experience/exposure, therefore, presents a complex combination of influences.

8.5.2.4 Curriculum

All teachers expressed their concern with the amount of content and number of assessments throughout the academic year. They all felt that '…the work… [was] continuous, you can't stop…' and that they did not '…have enough PE time…' with '…not much time to go and do things and practice things [skills] properly…'' Furthermore,

> *'…in the afternoon they just don't want to sit still anymore, they need to get up and move around and I don't think there's enough opportunity for that…' [Fg 2.1/5, P3]*

Interestingly, one teacher identified that academic subjects used to be taught in a more interrelated and practical manner but now '…maths lessons [are] in the classroom…' Physically active lessons have shown positive associations with PA (Norris et al. 2015). Although further investigation is proposed (Norris et al. 2015), active lessons may be beneficial in the current low prevalence of PA and FMS. Overall, due to the amount of curriculum content (delivery and assessments), particularly on core-subjects (English and maths), the ability for teachers to invest more time in developing the FMS is limited. Furthermore, the delivery of the curriculum is classroom-oriented reducing PA opportunities for children.

The barriers relating to lack of safety, parents and PA exposure ultimately sit outside of the primary school environment. Initiatives within local communities may, therefore, prove pivotal in increasing the PA engagement and FMS development of children living in ethnically diverse and deprived areas. Additionally, where possible, schools may be beneficial in compensating for the perceived complex external barriers (e.g. afterschool routines) by facilitating PA opportunities (e.g. active lessons; Norris et al. 2015) and ensuring that PE lessons are delivered. As interventions have been found to produce sustainable outcomes; making sure that opportunities for engagement during the school day are maximised is important (Lai et al. 2014). The barrier relating to the curriculum will be integrated into the exploration of barriers of PE delivery and planning later in this study.

As previously stated, the barriers outweighed the facilitators of PA engagement. The facilitators were perceived to be the school environment, teachers and structures within the local community.

8.5.2.5 School environment

Teachers identified numerous activities integrated into the school day (i.e. the 'daily mile', sports centre trips and clubs), that provided children with compulsory and optional opportunities to be physically active. Along with the activities, space and facilities within the school were also viewed as facilitative to PA engagement. These included the amount of space across various surfaces (i.e. 'playgrounds, fields, courts') and structures within the physical environment (i.e. 'trim trail').

The children attending schools in the same areas as teachers in the current study engage in at least 43% of their total objectively measured PA within the school environment (Eyre et al. 2015). Findings from the current study extend this work, providing insight into some of the contributing factors. Where opportunities to engage in PA are provided for children (e.g. the 'daily mile' and clubs), PA engagement significantly increases (Chesham et al. 2018). Further investigations into PA engagement levels following initiatives would provide insight into the long-term effectiveness beyond implementation. Additionally, children have been found to engage in significantly more moderate-to-vigorous PA when in outdoor environments compared to indoor environments (Eyre et al. 2015), which seem to be vast within the schools of the current study. Teachers perceiving the vast provision of activities and the physical environment of the school to facilitate PA engagement of children is therefore supported.

8.5.2.6 School teaching staff

The second main facilitative theme discussed was concerning the staff within the school. Having staff with designated roles, namely sports/PE teachers and external coaches, boosted childrens' enthusiasm for participation. Further facilitation of PA engagement was viewed in class teachers engaging in PA with children (e.g. presence on the playgrounds during break times, completing the daily mile); providing children with the idea that PA is for 'everyone' and everyone can, it is not just for PE lessons. Thus, along with the opportunities provided, the role modelling of teachers was also seen to contribute to PA engagement. The role of school staff is key to PA within the primary school environment, especially as children perceive staff involved in delivering PE as role models for engagement (Hills, Dengel and Lubans 2015). Thus, where staff are seen to have an interest and engage in PA as well as motivating/encouraging children to be physically active, a positive outlook is demonstrated.

8.5.2.7 Local area

The final main facilitator of PA was presented in facilities within the local area. The provision of parks and amenities such as 'gym equipment', sports centres and clubs were seen to provide children with PA opportunities in spite of the barriers previously identified.

The local park and amenities were seen to be facilitative of a child's PA engagement. Children are more likely to engage in PA in parks with a greater number of amenities (Kaczynski, Potwarka and Saelens 2008). It should be noted that a domain and context specificity regarding environmental influence on PA is suggested (Giles-Corti et al. 2005, Spengler et al. 2011). The schools in the current study being located in deprived and ethnically diverse areas in England, therefore, needs to be considered. Public open spaces located in deprived areas have been found to contain significantly fewer amenities when compared to more affluent areas (Crawford et al. 2008). Functional amenities as identified by teachers were reduced due to vandalism. Although parks and open spaces within the local environment may provide PA opportunities, the barriers relating to safety within the local area seem to outweigh them.

The provision of activities available at local sports centres and high schools within the area was also seen to promote PA engagement. Teachers indicated that often parents would sign children up to activities but withdraw when payments were due. This further reflects that opportunities may be available, but the barriers presented (i.e. finances), seem to prevent the facilitative contributors perceived by teachers from being utilised.

Considering the barriers and facilitators, it is evident that the school environment is perceived to be more conducive for PA engagement and FMS development than those external to it. When aiming to increase primary school children's PA engagement and FMS proficiency through interventions, utilising the school environment but aiming to remove present barriers within it (e.g. cost implications) may prove beneficial.

8.5.3 *Barriers to the planning and delivery of PE within the curriculum*

The curriculum structure and policies were viewed as the main barrier to PE planning and delivery. Within this, all teachers indicated that PE along with other foundation subjects (e.g. music and art) was not prioritised, 'children are pushed academically', focusing more on 'maths, English [and] science'. This was also reflective in the primary school curriculum in England including minimal guidelines for foundation subjects such as PE compared to core subjects (e.g. English). Despite investments in PE (e.g. 2012 Olympic sporting legacy, increased PE and sport premium funding allocations), teachers in the present study still do not perceive it as a priority (Callanan et al. 2015, Foster 2018a, Foster 2018b).

The time within the curriculum was also considered a barrier to PE planning and delivery. Teachers highlighted that PE lessons could not be planned effectively within the preparation session held one afternoon per week or taught within the one ~60-minute lesson per week. The lack of time available was partially attributed other subjects taking priority, requiring a greater amount of planning and teaching sessions during the week (e.g. math lessons taking place every day whereas PE was only taught once per week), along with the greater number of assessments within the academic year. Furthermore, teachers also identified that planning was hindered due to a lack of training and ideas. Planning, therefore, took longer and some found it 'difficult', to progress and regress the content. This indicates that the planning time available is seen as insufficient and the ability of teachers to utilise the limited time is further reduced due to a lack of initial training and CPD.

Teachers perceived links between the priority placed on core subjects, school targets and, governmental policy and assessments. The lack of priority on PE has been observed within the UK curriculum for at least 10 years, where the prevalence of core subject assessments unavoidably places superiority on them within the curriculum (Boyle and Bragg 2006). Teachers' internal school assessments, which may result in jobs being put in a 'bad position', were based more on children's achievement in 'reading, writing [and] maths'. Additionally, external assessments and outputs were seen to be focused on 'literacy and maths'. The Office for Standards in Education, Children's Services and Skills (Ofsted) is the department within the UK government responsible for inspecting and regulating services that provide education and skills in a learning context as well as services caring for children and young people (Ofsted 2018b). Schools in the UK, including those of the current study must, therefore, meet the education requirements set by Ofsted. Within the School Inspection Handbook provided by Ofsted in 2018 (Ofsted 2018a), specific inspections relating to English and maths were indicated ('Inspecting the impact of the teaching of literacy including reading' and 'Inspecting the impact of the teaching of mathematics'). The handbook also stated that 'schools will not be marked down because they are not 'tracking' science and foundation subjects in the same ways that they may be doing in English and mathematics' (Ofsted 2018a; pg 15). This further support of teachers' views, indicating the lack of extensive assessment and priority placed on PE within the curriculum compared to core subjects; a view that also mirrors perceptions of head and deputy headteachers (Domville et al. 2018). Currently, teaching staff are paid based on performance that is assessed objectively (e.g. assessment outcomes) and subjectively (e.g. through classroom observations) (DfE 2017). As assessments are seemingly more focused on English and maths, with more prescriptive guidelines and aims, the acknowledgement of performance-related pay may provide further insight into factors contributing to the priorities within the curriculum (DfE 2017).

A proposal for PE to become a core subject has been presented on behalf of the Physical Education Expert Group (Harris 2018). The grounds for this proposal include curriculum aims solely related to PE, health implications (physical and psychological) during childhood and adulthood, as well as benefits to the nation through health and economic prosperity (Harris 2018). The transition of PE from a foundation to a core subject would potentially overcome some of the barriers highlighted by teachers (i.e. priority) and tackle the low prevalence of PA engagement and FMS development. However, the already high demands of the current curriculum, without PE as a core subject, should be considered (e.g. assessments, planning within the allocated time). The entire curriculum structure would, therefore, need to be reviewed, particularly as the limited provision for PE (one-to-two lessons per week) is often missed due to other demands (e.g. English and/or maths tasks, halls being double-booked). It is essential that the incorporation of PE within the curriculum practically (e.g. planning, delivery and assessments) is matched with provision to ensure this proposal can occur.

8.5.4 *Teacher training for PE*

Exploring the teacher training barrier to PE planning and delivery, teachers discussed initial training and CPD as well as making suggestions for future training. Most teachers identified that their initial training included approximately ≤four hours of specific PE training. Those that did receive more had specialised in PE or were completing apprenticeships rather than qualifications such as a bachelor’s degree. None of the teachers were currently receiving CPD; the majority had never received any form of PE training. The current provision of initial PE training and CPD was sparse for teachers in the current study. Time spent during initial training has been found to be ‘insufficient’ since the late 1990s (Carney and Armstrong 1996, Harris, Cale and Musson 2012). A lack of opportunity for CPD was mainly attributed to the lack of priority and training needs placed on PE as previously discussed, thus funding was not directed toward PE CPD.

Although the training was not currently available, all of the participants showed an interest in completing PE training; providing suggestions for future CPD considering delivery, content and potential challenges. It was suggested that PE training be delivered practically once every term (~12-weeks) or once every half-term (~six-weeks). Firstly, teachers suggested shadowing more experienced teachers in neighbouring schools, to observe and discuss the devising process with staff teaching in similar demographic of children. Teachers also indicated that training could be delivered through workshops, integrating theory on child 'development and age milestones' as well as 'major and minor motor skills. With regards to the content of PE training, there was a need for 'more ideas' for 'indoors and outdoor' PE lessons and understanding of 'different ways of teaching the same thing', which may be achieved through the delivery methods previously discussed. Although training would be ideal for teachers, logistical challenges were acknowledged. For teachers to observe in other schools, replacement staff would be needed. A limitation of this was presented in the lack of funding available for replacement staff, thus the initial barrier to training found in funding allocation is further presented and discussed in more detail later. Though funding replacement staff may prove difficult, conducting training after school was also seen to be a potential issue due to teachers having other commitments.

Previous CPD in PE was shown to be effective (Harris, Cale and Musson 2012). The degree of effectiveness was hindered due to the short duration, limited engagement with teachers, reliance on resources as well as lack of support to follow-up on progress (Harris, Cale and Musson 2012). Teachers' proposals of the delivery and content for training in the current study may provide solutions to the shortcomings observed by Harris, Cale and Musson (2012). Namely the duration and follow-up as teachers suggested CPD delivery every ~six or ~12-weeks as well as limited engagement which may be overcome by the incorporation of shadowing, workshops and facilitated meetings. The additional barrier of funding towards future CPD was apparent in the current study and had been described as part of the reason for the current lack of it.

Most primary schools in England receive PE and sports premium funding determined by the number of pupils within the school in years one to six (aged five-to-ten-years) (DfE 2019). The most recent PE funding allocations (2018/2019) are provided where 'schools with 16 or fewer eligible pupils received £1,000 per pupil' or 'Schools with 17 or more eligible pupils receive £16,000 and an additional payment of £10 per pupil' (DfE 2019). This funding must be used to 'develop or add to the PE, PA and sports activities that your school already offers' and 'build the capacity and capability within the school to ensure that improvements made now will benefit pupils joining the school in the future years' (DfE 2019). The funding allocation varies within schools and depends on the specific needs of the pupils (Griggs 2018). Considering comments of teachers within the current study, funding may have been allocated elsewhere. Interestingly, in 2014 and 2015 81-to-86%, of schools were recorded to have utilised the PE and sports premium funding to train/upskill teachers (Callanan et al. 2015). The type of 'training and upskilling' was not specified by Callanan et al. (2015) thus it is unclear if the training was specific to the PE curriculum. This may partially explain the lack of funding perceived to be available for PE CPD in the current study.

Primary school staff across England have previously identified barriers impacting PE and sports premium being used effectively within primary schools (Callanan et al. 2015). Two of these barriers were also highlighted in the current study as barriers to PA and PE planning/delivery (limited expertise of staff, PE's accommodation into the curriculum); one was seen as a facilitator within the schools of the current study (physical space); and three that were not explicitly discussed (lack of engagement from Senior Leadership Team, challenges in sourcing coaches of a high quality and limitations to the time available to carry out the PE co-coordinator roles). Considering that funding allocation within schools varies and is independently determined, barriers may also vary between schools. Identifying the barriers within individual schools, as in the current study, is therefore key in improving PE CPD provision. Once they are identified they can be tackled, subsequently enabling the PE planning to be more efficient and PE to be delivered with more confidence.

8.5.5 PE Specialists

Teachers indicated mixed views on the employment of PE specialists in primary schools, although more benefits were highlighted than limitations. The main benefits of employing PE specialists were related to the delivery of PE, extra-curricular activities and reducing teacher's workload.

In terms of PE delivery, teachers viewed that PE specialists would ensure that PE lessons were always delivered at their designated times for each class. Proving children with the opportunity to be taught by a 'proper PE teacher' who they may '*treat…differently*', taking them more seriously within PE compared to their class teacher, due to their role within PE. This also links to the idea that delivery may be improved concerning education if PE specialists were to be employed; as they may be able to teach the children '*the language, the actual techniques of sport*', thus providing greater depth and specialism within the pedagogical approach. As well as within the curriculum, teachers saw a PE specialists' ability to run after-school clubs and make '…provision for …children that…excel in sport', beneficial as they would ensure that extracurricular activities were available for the children. Thu providing greater opportunities for children to develop skills and engage in more PA. The benefit of specialists leading extra-curricular activities also relates to the reduced workload for teachers. As they do not 'have the time in [their] working day' to consistently work on specific skills with individual children, a PE specialist would provide the means for this to still be achieved. Furthermore, it could also be part of their role to 'assess' children concerning PE targets, as teachers indicated that they also do not have the means or time for this to be completed as prescriptively as other subjects such as literacy and numeracy.

Within the limitations identified, discussions from teachers were mainly centred on PE specialists causing the subject of PE as well as engagement in PA to become more specialist. Other comments also related to their potential inability to direct children through the curriculum aims and teachers becoming de-skilled. It was seen that employing PE specialists would potentially reduce the perceived versatility of class teachers by children (e.g '*teaching…maths and the outside throwing the ball around or hitting the ball across the net*...'

Subsequently hindering the ability for children to have role models and see that they '*can be rounded like that, [they] don't have to just be a sports person*...' to engage in PA but that it is for everyone. Furthermore, teachers acknowledged that '*PE is taught through sport… [but] is quite different from sport*'. The employment of PE specialists was therefore seen to potentially hinder the children's development through the PE curriculum if a sports coaching approach was taken as opposed to a pedagogical approach when delivering PE. Additionally, some teachers felt that they were better suited to manage class behaviour as well as getting the best out of their class. Thus, being taught by PE specialists may also negatively impact children's progression through the PE curriculum due to class management. Finally, it was indicated that teachers run the risk of '*being de-skilled*' if PE is only taught by PE specialists. Although teachers felt that they did not receive enough teacher training for PE as previously discussed, it was highlighted that teachers need to be '*up-skilled all the time*'. Part of that was previously indicated through increased training opportunities as well as in this instance still teaching PE; providing teachers with the opportunity to practice and develop their skills and knowledge within the subject which would not be possible if solely PE specialists were delivering PE.

Considering the benefits and limitations presented by teachers in relation to the employment of PE specialists, recommendations were made. In light of the limitations relating to the potential for curriculum achievement being hindered and the deskilling of teachers, it was recommended that the delivery of PE could be split between class teachers and PE specialists. Partially indicating that coaches could teach the children '*occasionally*' as well as PE specialists being utilised to assess current progress and to guide teachers with their delivery of PE following the assessment. Another recommendation suggested, which in part extends PE specialists occasionally teaching, was that PE specialists could teach classes while teaching staff observed; thus, utilising the specific skills of PE specialists as well as aiding the upskilling of teachers. Previous findings reflect these perceptions that identify the potential importance of utilising coaches and specialists but also the need for teachers to be upskilled (Domville et al. 2018) This also relates to the suggestion previously stated by teachers of

PE training being achieved through '*shadowing*', overcoming the potential challenge of funding not being available for staff to be brought in to cover classes.

Several primary schools, including those within the current study, have employed '*PE specialists*' to aid the delivery of PE and/or extracurricular sporting activities (Jones and Green 2017). Teachers in the current study saw benefits to employing PE specialists, mainly linked to the delivery of PE being more specialists and consistent during the allocated times within the curriculum as well as subsequently reducing the workload of teachers. Considering the barriers to PE planning and delivery identified in the current study; namely, the lack of training and ideas along with the time constraints within the curriculum and lessons, the benefits identified by teachers support the use of PE specialists in that they in-part may contribute to these particular barriers being overcome. Notwithstanding, the limitations were apparent. Teachers felt that employing specialists may impact the delivery of the curriculum as PE is taught through sport but is not the same as teaching sport; hindering children's development. These concerns reflect literature (Capel and Blair 2008) that has shown that although coaches may understand and be competent at coaching sport, in some instances, there is very little understanding of the national curriculum in relation to PE as well as pedagogical approaches used to deliver it (Capel and Blair 2008). Thus, the delivery and subsequently the development of children concerning PE, may be compromised. Further to this, teachers concerns for PE and PA becoming a '*specialism*' with the sole use of PE specialists should be considered particularly as there is already a lack in achievement of the recommended guidelines for PA in males and females of primary school age in England (9 to 26% and 10 to 23%, respectively; (Owen et al. 2010, Townsend et al. 2015). Further disengagement from PE and PA could then have severely detrimental impacts to this already established concern. Finally, it was clear that teachers already felt as though they did not receive adequate training prior to or while working in the profession but were willing to receive CPD. Employing specialists and removing opportunities for them to teach PE was seen to potentially de-skill them further and was not what they desired.

8.6 Strengths and limitations

The current study presents some limitations. The majority of teachers recruited were female, classroom-based staff, providing perceptions of those with daily first-hand experience of the topic areas explored within the study. Due to the partial bias in the participants, results may be presented with a bias. The development could be made by including male teachers as well as PE specialists, Head Teachers, Senior Management and other staff not specifically based in classrooms but still involved in and around the planning and delivery of PE. This may enable greater insight and depth into specific areas (e.g. funding allocation, assessments) that have been identified in the current study.

All participants contributed within focus groups however in some instances, teachers simply agreed with others providing no personal insight and contributions to topics varied. As a result, data may be slightly biased based on the interest and depth of knowledge. In future, researchers should, therefore, ensure to probe for more detailed answers where participants have simply agreed. Furthermore, it should be noted that the results of the study are from the perspectives of teachers and therefore may not accurately portray parents themselves. It would, therefore, be prudent for future research to gain the perspectives of parents within this group and utilise results in conjunction with the current study.

The study focused on schools within deprived and ethnically diverse areas due to the apparent lack of FMS proficiency and PA engagement levels of children within these areas. A novel subjective insight into the current objectively assessed prevalence was therefore identified. To progress the current findings, teachers' perceptions in schools that are in deprived but not ethnically diverse areas, as well as affluent areas that are and are not ethnically diverse should be explored alongside objectively measured PA data. This would enable a comparison of findings as well as potentially contributing to the improvement of FMS development, PA engagement and the delivery of PE as related barriers and their prominence are seemingly complex.

8.7 Conclusion and practical application

The current study identifies that the primary school environment is perceived to be the main facilitator to FMS development and PA engagement by teachers. With the lack of safety within the local area and external exposure to PA engagement, mainly linked to the multifaceted limitations relating to parents, the school environment may be optimal when implementing interventions. Furthermore, it may be beneficial for parental limitations to be addressed where possible within the school environment; for example, providing free opportunities for children to engage in PA or education for parents regarding the benefits/importance of PA and ways to incorporate this into everyday living.

PE is not a priority within the primary school curriculum in England; even though it is the only statutory subject providing every child with the opportunity to develop their motor skills and subsequently PA across the lifespan. This is evident as there is a lack of specified initial training, CPD and comprehensive assessments that are monitored. The quality of PE delivery is therefore compromised, impacting children's lifelong PA, health and wellbeing. However, teachers seem willing to engage in training, but logistical challenges are present. Future interventions should consider ways of improving FMS proficiency and PA engagement levels that are practically viable in the current primary school climate. There should also be thoughts towards incorporating teacher training to aid with delivery, working towards sustainable models that can be continued in the absence of the researcher/specialist.

8.8 Thesis Map 3.0

Table 8.2. Thesis map 8.1

STUDY	AIMS	OBJECTIVES
Study Three: *“Barriers and facilitators of FMS development, pa engagement and PE: a primary school teacher’s perspective.”*	To explore a Teachers perspective of FMS development, PA engagement and PE curriculum in England. To provide additional context of study one and inform study four.	• To identify the perceptions and suggestions of the following topic of teaching staff in schools located in deprived ethnically diverse areas: ○ PA and PE in England ○ Barriers and facilitators of PA and motor development ○ PE within the curriculum and the delivery of PE ○ Training for PE • Incorporating PE specialists in the delivery of PE

KEY FINDINGS:

- Teachers perceived PA and PE to have positive impacts on children physiologically, psychologically and socially.
- The main barriers to PA engagement and FMS development were highlighted as
  - lack of safety in the area
  - parents (priority placed on PA, cultural norms, lack of income, large family size)
  - lack of exposure/experience to PA engagement
  - crowded curriculum
- The main facilitators to pa engagement and motor development were highlighted as:
  - the physical school environment
  - teaching staff
  - local area

- PE was not prioritised within the curriculum; maths, English and science are at the forefront, mainly due to internal and externally set assessments and curriculum targets.
- Staff felt that they lacked initial training and continued professional development. They would however be happy to undertake PE training but were aware of the logistical challenges (e.g. teaching cover).
- Teachers saw PE specialists as beneficial and that they would raise the profile of PE, ensure the provision of lessons and clubs, and improve sports. However, limitations were also highlighted in that PE is taught through sport and should be taught differently to sport. Teachers were also aware that they may become deskilled in their delivery and that PE specialists may not be able to support their classes in the way that they can.

9.0 STUDY FOUR: THE EFFECTS OF INCORPORATING INTEGRATIVE NEUROMUSCULAR TRAINING IN PHYSICAL EDUCATION DURING MIDDLE CHILDHOOD ON FUNDAMENTAL MOTOR SKILLS AND HEALTH-RELATED FITNESS MEASURES

9.1 Thesis map 9.0

Table 9.0. Thesis 9.1

STUDY	AIMS	OBJECTIVES
Study One: *"Fundamental motor skills of children in deprived areas of England: a focus on age, gender and ethnicity."*	To asses FMS mastery of males and females' children schooling in deprived ethnically diverse areas in England.	• To examine process and product FMS of males and females in early and middle childhood. • To compare process and product measures of FMS in males and females as well as Black, White and Asian ethnicities between and within children in early and middle childhood.
Study Two: *"The mediating roles of perceived motor competence and health-related fitness for children's physical activity."*	To examine factors affecting motor competency and moderate to vigorous physical activity engagement. Exploring and objective context for study one.	• To examine FMS, MVPA, PMC and HRF during early and middle childhood. • To assess the indirect associations between FMS and MVPA bi-directionally through PMC and HRF during early and middle childhood.
Study Three: *"Barriers and facilitators of FMS development, pa engagement and PE: a primary school teacher's perspective."*	To explore a Teachers perspective of FMS development, PA engagement and PE curriculum in England. To provide additional context of study one and inform study four.	• To identify the perceptions and suggestions of the following topic of teaching staff in schools located in deprived ethnically diverse areas: o PA and PE in England o Barriers and facilitators of PA and motor development o PE within the curriculum and the delivery of PE o Training for PE o Incorporating PE specialists in the delivery of PE

STUDY ONE, TWO AND THREE SUMMARY:

Study One identified that there is a lack of FMS proficiency (process and product) achievement in children attending schools in deprived ethnically diverse areas in England; particularly in females in middle childhood and children from Asian ethnic backgrounds. Furthermore, within this same sample, *Study Two* and *Three* explored partial explanations of *Study One* findings. HRF explained greater variance in the associations between FMS and MVPA compared to PMC during early and middle childhood. Subjective explanations of the lack of FMS proficiency identified barriers mainly within local and home environments. It was therefore proposed that the school environment would be the most facilitative for FMS development and PA engagement where the barriers within schools could be overcome. Furthermore, combining PE delivery between PE specialists and teachers may be the most practically appropriate approach for PE and FMS interventions. Thus, *Study One* highlights children living in these areas may benefit from interventions aiming to improve FMS while study two and three suggest that FMS interventions may be more effective if elements of HRF are incorporated into the intervention programme taking place within the school environment.

Study Four: ***"The effect of integrative neuro muscular training on fundamental motor skills and health-related fitness in nine-to-ten-year-old"***	**To assess the effect of a 6-week INT programmed on FMS and HRF measures in nine-to-ten-year-old males and females at pre-, post and post-6-week intervention period.**	• **To asses FMS and HRF measures at baseline** • **To implement a 6-week INT programme** • **To assess FMS and HRF measures immediately post the intervention programme** **To assess FMS and HRF measures post 6-weeks intervention**

9.2 Abstract

This study sought to determine the effects of a six-week Integrative Neuromuscular Training programme, on Fundamental Motor Skills and health-related fitness measures during middle childhood. It was the first study to incorporate Integrative Neuromuscular Training into the Physical Education curriculum for nine-to-ten-year-olds in deprived and ethnically diverse areas in England where FMS proficiency is low. Following ethics approval, 59 children attending schools in deprived and ethnically diverse areas in England were assigned to a control (CON-group) *n*=31 or intervention group (INT-group) *n*=28. Fundamental Motor Skills were assessed using the TGMD-2 and HRF measures included 10m sprint speed, standing long jump and hand-grip strength. Assessments were conducted pre-, immediately-post and post-six-weeks following intervention completion. The results indicate significant improvements in total and locomotor skills from pre- to post-intervention in the INT-group only (p<0.05). While both the INT and CON-groups ran significantly faster post-, only the INT-group sustained this improvement to post-six-weeks (p=0.001). No significant changes were shown in object-control skills, standing long jump distance or hand-grip strength. These data infer that incorporating Integrative Neuromuscular Training into the Physical Education curriculum will promote greater improvements in Fundamental Motor Skills of children in deprived and ethnically diverse areas in England; where the expected development of such skills appears to be lacking. Subsequently, Fundamental Motor Skill proficiency is proposed to relate to physical activity positively and obesity inversely. The novel findings present Iintegrative Neuromuscular Training as a practically viable contribution to tackling the current low proficiency of FMS.

9.3 Introduction

Regular engagement in PA is vital for physical, psychological and social development during childhood (Janssen and LeBlanc, 2010). However, many children are not engaging in sufficient amounts of PA which is tracking into adolescence (Townsend et al., 2015; World Health Organisation, 2017). An important predictor of adolescent PA engagement is a child’s ability to perform FMS (Lopes et al., 2011). These FMS are the foundational skills, and the “building blocks” of more complex skills, much like that required for sporting situations (Logan et al., 2018). Presently, children in deprived and ethnically diverse areas in England demonstrate low levels of FMS mastery and PA engagement (*see Study One; section six,* Eyre et al., 2015, 2018).

The combination of cognitive processing, correct FMS patterns and effective muscle force production are important in FMS development (Moody et al., 2014). The pre-pubertal stages of childhood are considered as an opportune time to target FMS development as before children reach puberty they experience greater sensitivity to training-induced adaptations (Fort-Vanmeerhaeghe et al., 2016). Thus, children’s FMS learning experiences must encompass opportunities to learn a variety of generic/ basic movement patterns and develop the necessary strength to carry out FMS efficiently and safely (Lloyd and Oliver, 2012). An environment that facilitates such learning experiences has been highlighted in primary school Physical Education (PE) lessons (Inman et al., 2011; Naylor and McKay, 2009). The PE curriculum in England incorporates mandatory and explorative guidelines; focusing on children being able to demonstrate and use FMS independently and in combination (DfE 2013). Furthermore, children are expected to develop control, balance, flexibility, technique and strength (DfE 2013). The levels of proficiency expected are Key-Stage dependent; beginning with acquisition during Early Years Foundation (three-to-five-years-old) and progressing to mastery and application during Key-Stage 2 (eight-to-11-years-old). However, many children in England are not progressing through the FMS elements of the PE curriculum as expected by the age of ten-years-old, which is shown through their poor FMS proficiency attainment as shown in study one (*see section 6.0*) and supporting research (Eyre et al., 2018).

A successful approach to improving FMS during childhood has been demonstrated in INT (Fort-Vanmeerhaeghe et al., 2016). INT programmes aim to develop skill and health-related components of physical fitness by utilising strength and conditioning that incorporates dynamic stability, agility, resistance and plyometric activities through basic motor skills (object-control and locomotor) (Myer et al., 2011). Thus individuals are provided with the opportunity to develop the quality of movement and, the strength and power to perform them (Fort-Vanmeerhaeghe et al., 2016; Myer et al., 2011); which is important for FMS development as shown in study two. Though the aims and benefits of INT are reported, and in-part align with elements of the PE curriculum in England relating to FMS (DfE, 2013), much of the literature has been conducted within athletic training environments (Fort-Vanmeerhaeghe et al., 2016).

Only a small number of studies have employed INT in primary school settings with evidence of beneficial effects for strength, power, fitness and FMS as well as being time-efficient and safe for five-to-eight-year-olds (Duncan et al., 2017; Fort-Vanmeerhaeghe et al., 2016). INT programmes have been conducted in 15-minute sessions, twice a week for eight-weeks (Faigenbaum et al., 2011) and 40-minute sessions once a week alongside one statutory PE lesson for ten-weeks (Duncan et al., 2017). The Primary school academic calendar in England is based on six, six-week teaching blocks, during which the focus of PE lessons often changes every between blocks. Therefore, although previous approaches report benefits, they may not be feasible to embed into the curriculum long-term based on the structure of the academic calendar; where the delivery of PE is already shown to be compromised by multiple constraints (e.g. lack of priority, lack of training) as highlighted in study three (*see section 8.0*). As such it would, therefore, be more appropriate to align the duration of INT interventions for the assessment of INT efficacy within the current six-week structure. Furthermore, the sustainability of the intervention and its effects have not been determined (Duncan et al., 2017, Faigenbaum et al., 2011), thus understanding the impact INT has on the long-term progression of children through the PE curriculum is limited. In addition, current studies have only observed INT in five-to-eight-year-olds, though poor FMS have been identified in children during middle childhood (nine-to-ten-year-olds) in Asia, South America (Díaz et al., 2015, Mukherjee et al., 2017) as well as children from deprived and ethnically diverse backgrounds in England as shown in study one. Considering the proposed influence of FMS on PA engagement and obesity prevalence (Stodden et al., 2008) and HRF observed in study two, INT within this age group (nine-to-ten-year-olds) may be a useful approach for increasing skill attainment and improving child health trajectories; however, this has not yet been examined in this population.

As such, the present study sought to determine the effects of implementing a six-week INT programme on FMS proficiency and health-related fitness measures (HRF) in middle childhood (nine-to-ten-year-olds).

9.4 Method

Study design

Quasi-Experimental study design was conducted to examine the effect of a 6-week integrative neuromuscular training (INT) programme on FMS proficiency (process and product), perceived motor competence, strength measures and PA engagement. Two groups of children, that were matched at baseline, took part from separate schools to reduce the likelihood of a cross-over effect that may have resulted from teacher/peer teaching. Repeated measures were used, and assessments took place a three time-points; baseline (one-week prior to intervention), post (one-week post-intervention), and post-two (six-weeks following post-assessment). The Primary school PE curriculum in England is generally broken down into six-week segments aligning with the term-time and school holidays. A similar intervention duration and time between post and post-two assessments were therefore adhered to within *Study four* with the aim of enhancing the practical relevance, as well as keeping within the scope of information provided by teachers (*see section 8.5*). Post-two assessments enabled the observation of effects beyond post-assessment (e.g. duration of effects, potential delayed effects), subsequently providing a greater understanding of the intervention impact.

Participants

Following institutional ethics approval and Head Teacher approval, 91 pupils in year-5 were approached during their year-group assembly from two primary schools, selected through convenience sampling, in deprived areas of central England. A priori power calculation indicated that, in order to detect a medium effect size (0.5) at p= .05 and 80% power using a repeated measures ANOVA with 2 groups and 3 assessment occasions a sample size of 28 was required. In total 60 participants provided informed parental consent and were included in the study if they were identified as ‘health’ by their consenting parent/guardian. The two schools were then randomly assigned into the INT group (n= 29, 9.96 ± .29 years-old) and the control (CON) group (n= 31, 9.62 ± .48 years-old). Anthropometric, FMS (process and product) and HRF data were collected in the school hall and assessments were conducted as previously stated.

Anthropometric data
Please refer to *section 5.3*

Process-oriented assessment of Fundamental Motor Skills
Please refer to *section 5.5.1*

Product-oriented assessment of Fundamental Motor Skills
Please refer to *section 5.5.2*

Health-related fitness measures
Please refer to *section 5.6*

Intervention regime
The intervention was delivered by the principal investigator using a direct instruction approach supported by demonstrations, in the school hall across six 50-minute sessions; replacing one of two teacher-led PE lessons (invasion games). Each consisted of a ~five-minute warm-up (McGowan et al., 2015; Morgan et al., 2013); ~40 minutes of the main session including child-specific resistance exercises incorporated into games as guided by the Key-stage 2 PE curriculum aims in England (Faigenbaum et al., 2011, DfE 2014, Fort-Vanmeerhaeghe et al., 2016, Foster and Adcock 2016, Duncan et al., 2017); and a ~five-minute cool down (McGowan et al., 2015; Morgan et al., 2013; *see Appendix 9.1*). The whole class was present during sessions and the class Teachers or Teaching Assistant was present to provide support in behaviour management and observe. As described by Duncan et al. (2017), with regard to the efficacy of movement interventions based in schools, the INT program substituted one PE session to reduce disruption to the school day. The nature of the program was such that it could potentially be integrated into the primary school curriculum and employed by teachers; considering time, space, equipment, cost and developmental stage.

The CON-group continued to engage in their regular two PE lessons per week (one delivered by the class teacher and the second delivered by a PE specialist) across the six-week training intervention period. These sessions lasted ~50 minutes and included athletics and rounders, aligning with the Key-Stage 2 PE curriculum in England and targeting both locomotor and object control skills.

Statistical analysis

Participants' data were only included in the analysis if all intervention and PE classes were attended as well as all assessment points met (pre, post and post-six) with all variables measured. Means and SD's were calculated for all variables and a repeated measure analysis of covariance (ANCOVA) (2x3) was conducted using IBM SPSS Statistics software (v.24 IBM Corp Amork USA) to assess main effects and interactions for time (pre vs. post vs. post-six) and group (INT vs. CON), controlling for maturation. Where significant differences were identified post-hoc pairwise comparison (Bonferroni adjusted) was conducted to specify the location of the differences and effect size (Cohens-*d* calculation *(d*; Lakens 2013) was used to identify the magnitude of change.

9.5 Results

Participant study flow

Figure 9.1a presents the flow of participants through the study from the provision of consent to data analysis. Of the 60 participants that provided informed consent (66% response rate) only one participant was removed from the INT-group due to being absent during the post-assessment point.

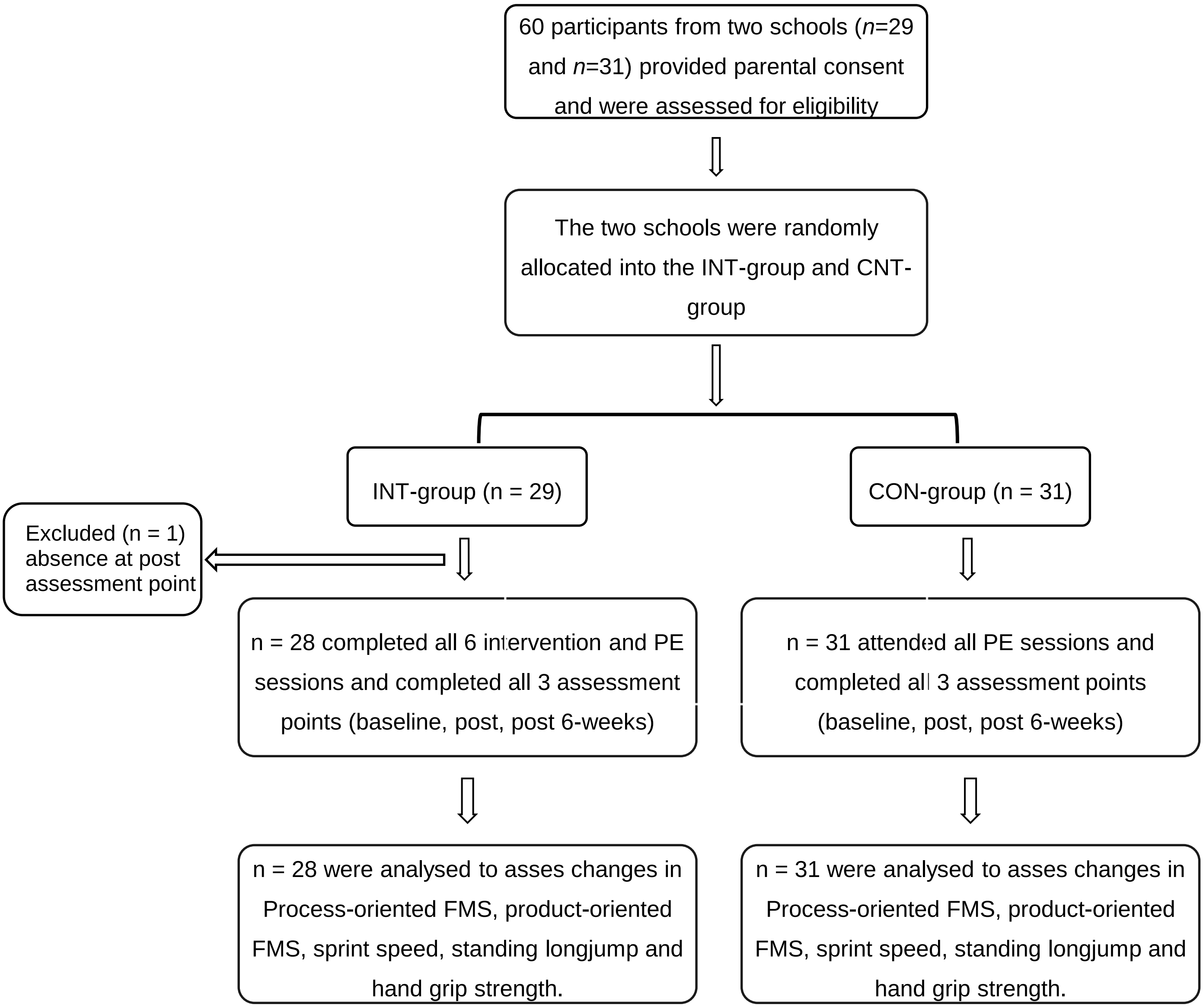


Figure 9.1a. Flow of participants throughout the intervention. ***INT*** *= Integrative neuromuscular training,* ***CON*** *= control.*

There were no significant differences across anthropometric measures, FMS or HRF measures between the INT and CON-group at baseline (*see Table 9.2 and 9.3*).

Table 9.2. Participant demographics of anthropometric measure pre-intervention.

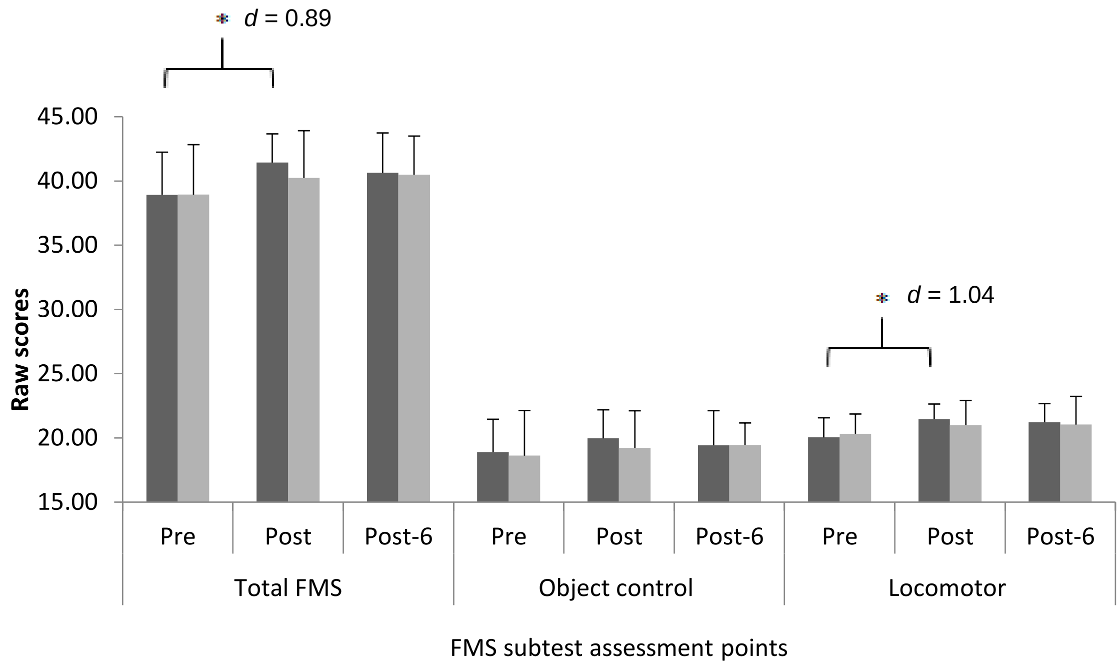
		Control Group mean (SD)		Intervention Group mean (SD)	
N		31		28	
Gender (Boys : Girls)		19:12		15:13	
Age (yrs)		9.96 ± 0.29		9.62 ± 0.48	
Ethnicity (%)	**Asian**	0		19	
	Black	20		35	
	White	80		46	
Standing Height (cm)		140.46 ± 6.22		140.72 ± 7.01	
Seated Height (cm)		71.29 ± 2.62		69.8 ± 2.89	
Leg Length (cm)		69.17 ± 4.48		70.91 ± 5.45	
Mass (kg)		36 ± 7.41		35.35 ± 7.69	
		Male	*Females*	*Male*	*Females*
BMI (Kg/M^2) (%)	**Overweight**	31.58	8.33	13.33	7.69
	Obese	0	0	0	7.69
	Severely obese	10.53	0	6.67	0

Table 9.3. Participant demographics of FMS and HRF measures pre-intervention.

Measure	Control Group Mean ± SD	Intervention Group Mean ± SD
	Pre	*Pre*
Total FMS (raw score)	38.94 ± 3.89	38.93 ± 3.31
Object control Skills (raw score)	18.61 ± 3.52	18.89 ± 2.56
Locomotor Skills (raw score)	20.32 ± 1.54	20.04 ± 1.53
Sprint Speed (s)	2.51 ± 0.17	2.57 ± 0.19
Standing Long Jump (cm)	122.87 ± 19.32	111.39 ± 20.79
Hand Grip (kg)	17.01 ± 3.67	15.67 ± 2.65

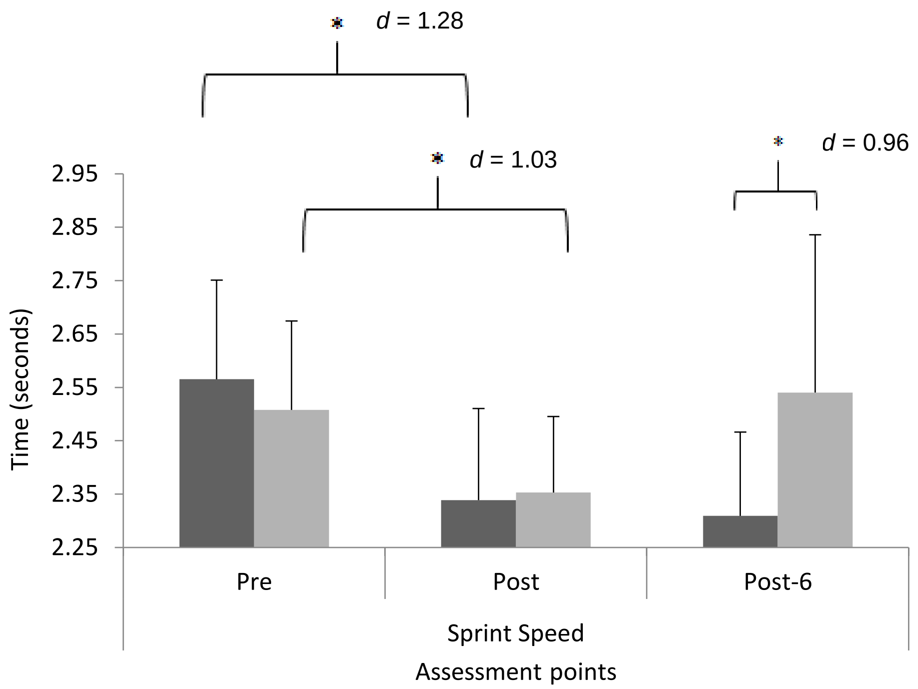
Repeated measures ANCOVA results, controlling for maturation, revealed maturation was not a significant covariate. A significant improvement with large effect sizes were shown in total and locomotor FMS of the INT-group pre- to post-intervention (M_{Post} - M_{Pre}=2.99 and 1.43; *d*=0.89 and 1.04; p<0.05) but not in the CON-group. This improvement was maintained at post-six (M_{post}=2.34 ± 2.35 and $M_{post\text{-}six}$=2.31 ± 2.54). No significant changes were shown in object-control skills of either group (*Figure 9.1*). Overall children lacked the achievement of all components for each skill across object-control and locomotor skills (*Figure 9.1*).

A group (INT vs. control) by time (pre vs. post vs. post-six) interaction was indicated for sprint speed; Bonferroni post hoc pairwise comparison identified participants in both the INT and CON ran significantly faster post-intervention than pre- (M_{Post} - M_{Pre}=-0.23 vs -0.14; *d*=1.28 and 1.03; p<0.001). The improved sprint speed was maintained from post to post-six assessments for the INT-group but not the CON-group, (2.34 ± 0.17 to 2.31 ± 0.16 vs. 2.35 ± 0.14 to 2.54 ± 0.30), resulting in there being a significantly faster sprint speed for INT vs CON-group at post-six, showing a large effect size (*d*=0.96; *p*<0.001). No significant main effects were shown in SLJ distance or handgrip strength.



**Significant difference between time points measured: p< .05*

Figure 9.1. Pre-, post and post-six scores for total FMS, object control and locomotor skills of the intervention group (dark grey) and control group (light grey).



**Significant difference between time points measured: p< .05*

Figure 9.2. Pre-, post and post-six sprint speed times of the intervention group (dark grey) and control group (light grey).

9.6 Discussion

This is the first study to explore the effects of a school-based, 6-week INT programme on FMS and HRF in children during middle childhood in deprived areas in England. Although INT has been examined in children during early childhood (five-to-eight-years; Faigenbaum et al., 2011, Duncan et al. 2017), where FMS are typically developing, no study to date has examined whether INT is effective during middle childhood where children are not attaining FMS mastery as expected for their age. As such, the current study extends work on this topic. The key novel findings demonstrated the effectiveness of INT over six-weeks, during middle childhood, in significantly improving total and locomotor FMS however a time by group interaction was not shown. Additionally, sprint speed with large effect sizes (Häger-Ross and Rösblad, 2002). Importantly, the improvement in sprint speed was maintained at post-six assessments, identifying for the first time, that these improvements are sustainable when the dose is removed.

The significant improvement in the quality of movement – locomotor FMS – shown pre- to post-INT was maintained by the INT-group at post-six assessments which aligns and extends previous research in younger children (Duncan et al., 2017). When considering individual subtests of the TGMD-2, only locomotor FMS significantly improved and is therefore suggested to be the main contributor to the significant improvement seen in Total FMS. Thus, the INT programme prescribed in the current study may have partially facilitated the development of the efficient combining of cognitive processing, correct FMS patterns and force production (Moody et al., 2014). Inducing a greater benefit to locomotor skills proficiency, from pre- to follow-up compared to object-control skills (Moody et al., 2014). Contrary to previous findings in younger children (Duncan, Eyre and Oxford 2017), a group by time interaction was not shown; although the INT-group significantly improved in their quality of total FMS and locomotor skills, this was not significantly greater than the CON-group. The use of INT to improve FMS is therefore suggested to be effective during middle childhood although additional means may need to be considered for greater magnitudes of change. Considering previous assertions that there are no specific durations for interventions aiming to improve FMS (Logan et al. 2012, Robinson 2017), results suggest that INT may require a minimum duration for the development of specific FMS subtests. The extent to which its effectiveness over six weeks, exceeds that of statutory PE, compared to ten-weeks (Duncan, Eyre and Oxford 2017) however, may require further investigation into the specific components of the programme (i.e. exercises, intensities, rest period).

Further explanation of the lack of improvement in object-control skills may be found in that they develop after locomotor skills, having greater component complexity and perceptual demand compared to locomotor skills (Morgan et al., 2013). Thus, improving object-control skills is more challenging and may require teaching and practice with greater intensity/duration (Morgan et al., 2013). Interestingly the object-control skills of the CON-group who engaged in statutory PE also did not significantly improve. Both groups lacked mastery achievement across all skills which are reflective of children in a similar population as shown in *Study One* (Adeyemi-Walker et al., 2018). Though proficiency of FMS significantly improved for the INT-group, many of the participants still did not achieve TGMD-2 scores that indicated mastery (achievement of all skill components). Children living in deprived and ethnically diverse areas, such as those in the current study, have been found to lack FMS mastery achievement from early to middle childhood (four-to-five and nine-to-ten-years-old (*see study one,* Eyre et al., 2018). This would, therefore, suggest, that to increase proficiency in object control skills during middle childhood within similar populations, interventions and the PE curriculum may need to focus on these skills for longer periods (>six-weeks) or potentially increase PE session/opportunities for skills to be taught and practiced during the week (e.g. break time, lunchtimes, after-school clubs).

The findings also demonstrate significant improvements in sprint speed in the INT-group and CON-group from pre- to post-assessments. However, follow-up data (post-six) showed that the INT-group maintained the level of improvement which was significantly better than the CON-group where sprint speed regressed compared to post-assessments; reflective of results found in locomotor skills. Therefore, INT and PE seem to be an effective method of improving sprint speed within this age group, however, INT training presents longer lasting improvements in both the product and movement quality of sprinting.

9.7 Conclusion and future research

The results of the current study confirm suggestions/conclusions made by Faigenbaum et al., (2011) and Duncan et al., (2017) in suggesting a shorter dose of INT (six-weeks vs. ten-weeks) with greater alignment to the academic timetable, alongside statutory PE facilitates improvements in total FMS and specifically locomotor skills. However, this study develops the experimental data within a unique group (nine-to-ten-year-olds living in a deprived and ethnically diverse area). As this is the first study to assess INT in a primary school environment within this age group, the findings presented in the current study require additional investigation in a school-based environment with a duration reflecting the current curriculum structure in England. This will further develop an understanding of the practicality of INT integration into the PE curriculum in England. Future research should aim to assess the effects of INT on related curriculum aims (e.g. FMS, strength) within each primary school year group. Exercises should be recorded precisely (e.g. volume, frequency and intensity), as well as the inclusion of follow-up assessments as children, progress across the six-week teaching periods throughout the academic year where PE topics change. This may provide a more comprehensive idea of the effects of INT when integrated into the PE curriculum, particularly relating to duration and frequency as highlighted in the current study.

Future research should aim to utilise PA outcomes to provide broader insight into the integration of INT into the PE curriculum. The current study aimed to examine the effect of INT on habitual PA but due to the lack of compliance and valid datasets, this data did not hold adequate power for inclusion. This would be a logical next step to further understanding the utility of INT in children. Additionally, considering the direct associations between PMC and FMS shown to emerge during middle childhood in *Study Two*, the assessment of PMC should also be considered where children of the same age group or older are assessed. The intervention was also delivered by a movement trained expert to determine the efficacy of INT in this age population. To further understand the practical sustainability of integrating INT into the PE curriculum, future research should investigate the delivery of programmes by class teachers and PE specialists instead of researchers, as they currently deliver the PE curriculum in England. If primary school teaching staff were to successfully deliver INT programmes considering elements such as current workloads/ demands, time available and appropriate knowledge and skills for delivery (Faigenbaum et al., 2009), practically integrating INT into the PE curriculum in England may be more viably sustainable in the long-term. This should include exploring potential training needs for delivery as poor technique and inappropriate training loads resulting from a lack of supervision have been associated with increased injury risk (Faigenbaum et al., 2009).

Introducing INT into the primary school PE curriculum has the potential to increase a child's progression through FMS development and improve FMS where a lack of mastery may be present. Subsequently improving children's development through the motor skill aims within the PE curriculum England related. These improvements may then develop effective transitioning of FMS into more complex skills and increase PA engagement levels, reducing the risk of obesity. Alongside the benefits of INT shown, it is also practically viable considering the current curriculum set-up, time allocated for PE as well as facilities available within schools. Further understanding of the sustainability of INT as a successful FMS intervention method from a teacher's perspective (e.g. training, time available, resources, and delivery structure) is needed.

9.8 Thesis Map 9.1

Table 9.4. Thesis map 9.1

STUDY	AIMS	OBJECTIVES
Study Four: *“The effect of integrative neuro muscular training on fundamental motor skills and health-related fitness in nine-to-ten-year-old”*	To assess the effect of a 6-week INT programmed on FMS and HRF measures in nine-to-ten-year-old males and females at pre-, post and post-six weeks intervention period.	• To asses FMS and HRF measures at baseline • To implement a 6-week INT programme • To assess FMS and HRF measures immediately post the intervention programme • To assess FMS and HRF measures post-6--weeks intervention

KEY FINDINGS:

- Integrative Neuromuscular Training improves total FMS and locomotor skills in nine-to-ten-year-olds but not object control skills.
- Sprint speed significantly improved in the INT and CON-group pre- to post intervention. Post-six weeks assessment showed INT maintained a faster speed and ran significantly faster than con group who ran slower than at post assessments.
- SLJ and handgrip did not change significantly.

SUMMARY:

Study Four results suggest that incorporating Integrative Neuromuscular Training into the PE curriculum in England may be more beneficial to improving total and locomotor skills FMS mastery as well as sprint speed of nine-to-ten-year-old children compared to standalone PE.

9.9 Thesis map overview

Table 9.5. Thesis map overview

STUDY	AIMS	KEY FINDINGS
Study One: *"Fundamental motor skills of children in deprived areas of England: a focus on age, gender and ethnicity."*	To asses FMS mastery of males and females' children schooling in deprived ethnically diverse areas in England.	• Children in middle childhood had significantly greater mastery of total FMS, object control, locomotor skills and product scores than children in early childhood. • Boys in middle childhood demonstrated significantly greater mastery of total FMS, object control skills and product scores than their female counterparts. • Children of black and white ethnic backgrounds had significantly greater locomotor skill mastery than those of Asian ethnic backgrounds.
Study Two: *"The mediating roles of perceived motor competence and health-related fitness for children's physical activity."*	To examine factors affecting motor competency and moderate to vigorous physical activity engagement. Exploring and objective context for study one.	• PMC did not mediate the relationship between FMS and MVPA in either direction. • The relationship between FMS and MVPA was mediated through HRF during early and middle childhood
Study Three: *"Barriers and facilitators of FMS development, pa engagement and PE: a primary school teacher's perspective."*	To explore a Teachers perspective of FMS development, PA engagement and PE curriculum in England. To provide additional context of study one and inform study four.	• Teachers perceived pa and PE to have positive impacts on children physiologically, psychologically and socially. • The main barriers to pa engagement and FMS development were highlighted as ○ Lack of safety in the area

- Parents (priority placed on pa, cultural norms, lack of income, large family size)
- Lack of exposure/experience to pa engagement
- Crowded curriculum

- The main facilitators to pa engagement and motor development were highlighted as:
  - The physical school environment
  - Teaching staff
  - Local area
- PE was not prioritised within the curriculum; maths, English and science are at the forefront, mainly due to internal and externally set assessments and curriculum targets.
- Staff felt that they lacked initial training and continued professional development. They would however be happy to undertake PE training but were aware of the logistical challenges (e.g. Teaching cover).
  - Teachers saw PE specialists as beneficial and that they would raise the profile of PE, ensure the provision of lessons and clubs, and improve sports. However, limitations were also highlighted in that PE is taught through sport and should be taught differently to sport. Teachers were also aware that they may become deskilled in their delivery and that PE specialists may not be able to support their classes in the way that they can.

Study Four: *"The effect of integrative neuro muscular training on fundamental motor skills and health-related fitness in nine-to-ten-year-old"*	To assess the effect of a 6-week INT programmed on FMS and HRF measures in nine-to-ten-year-old males and females at pre-, post and post-six weeks intervention period.	• Integrative neuromuscular training improves total FMS and locomotor skills in nine-to-ten-year-olds but not object control skills. • Sprint speed significantly improved in the INT and con-group pre- to post intervention. Post-six weeks assessment showed INT maintained a faster speed and ran significantly faster than con group who ran slower than at post assessments. SLJ and handgrip did not change significantly.

10.0 GENERAL RESEARCH OVERVIEW

This thesis sought to investigate the current prevalence of FMS proficiency of children in early and middle childhood of Asian, Black and White ethnic backgrounds living in a deprived and ethnically diverse area in England. Further to this, the work aimed to identify mechanisms influencing the current prevalence. This was achieved through qualitative and quantitative means in order to subsequently inform an intervention through objective and subjective findings. The intervention aimed to tackle the initial FMS proficiency demonstrated by addressing some of the influential mechanisms identified.

The primary objectives were:

1) To observe/compare objective and subjective FMS proficiency measures of primary school boys and girls during early and middle childhood from different ethnic backgrounds (Black, White European and Asian) living in a deprived area in England.

2) To observe the direct and indirect associations between FMS, PA, PMC and HRF within this group.

3) To explore the perceived barriers and facilitators of FMS development, PA engagement and PE encountered by these children in early and middle childhood qualitatively with primary school teaching staff.

4) Objectives 1, 2 and 3 were then used to inform the 4th objective of investigating the effects of a 6-week integrative neuromuscular training programme on FMS and HRF measures.

10.1 **Do FMS proficiency levels vary by age, sex and/or ethnicity in early and middle childhood living in a deprived and ethnically diverse area?** (*Study One: Section 5.0*)

Study One developed the literature of FMS within children during early and middle childhood from Asian, Black and White ethnic backgrounds living in a deprived area in England.

Study One addressed the first objective by observing ethnicity. The proficiency levels of FMS varied between children from different ethnic backgrounds. Asian children demonstrated the poorest proficiency of locomotor skills compared to Black and White children irrespective of age. This was the first study to observe ethnic differences in FMS proficiency during early and middle childhood. Where solely children in early childhood have been explored those from South Asian backgrounds demonstrated poorer locomotor skills than their counterparts of Black and White ethnic backgrounds (Eyre, Walker and Duncan 2018). Thus, this thesis extends this work identifying that children from Asian backgrounds present poorer locomotor skills at both the expected acquisition stage (four-to-five-years-old) as well as the expected mastery stage of FMS development.

This study also addressed the first objective by examining FMS proficiency concerning the age of the sample. Overall boys and girls in middle childhood demonstrated better proficiency of FMS (total, object-control and locomotor skills) as well as higher product scores than children in early childhood irrespective of ethnicity. The process findings reflect the age-related phases and stages of motor development (Gallahue, Ozmun and Goodway 2012). Children in early childhood years are acquiring FMS which is reflective of the lower proficiency compared to children in middle childhood; who would have been taught FMS since early childhood and been provided with opportunities for skills to be practiced and reinforced (Morgan et al. 2013), in part through the PE curriculum in England (DfE 2014). Thus, FMS are developing in children from early and middle childhood who live in deprived areas that are ethnically diverse.

Progression of proficiency shown in study one is seemingly encouraging however, the expected mastery achievement was not achieved (Gallahue, Ozmun and Goodway 2012) and the sample also showed ethnic variations. Skills of object control and locomotor subtests were not mastered by all middle childhood participants (*see table 6.1)*. Previous findings in England have shown low FMS proficiency in preschool children (Foulkes et al. 2015) and five-year-olds (Eyre, Walker and Duncan 2018) but there is a limited exploration in England of older age-groups. *Study One* shows novel findings, identifying that the low proficiency during early childhood is also present during middle childhood.

The first objective was also explored by observing the interaction between FMS and sex. During middle childhood, study one also showed sex differences; males outperformed females in total FMS, object control and composite score irrespective of ethnicity. These sex differences have also been found in children of the same ages in different countries (Hume et al. 2008, Barnett et al. 2010). This may in part be explained through multiple components including increased PA engagement in males (Townsend et al. 2015), greater enjoyment experienced by males when engaging in sport and game type PA (Seabra et al. 2013) and/or socialisation of PA engagement through significant other/peer influence which leads males to engage in more object control activities (Maturo et al. 2013, Martin et al. 2013). All of which provide males with greater opportunities for FMS, particularly object control skills, to be taught as well as practiced and therefore develop (Logan et al. 2012). It is at this stage that children are expected to develop their mastered FMS into more sport-specific skills. However, if the majority of children from a deprived and ethnically diverse area are not able to master skills and a greater lack of mastery is shown in females then the transition of FMS and children's ability to progress in more complex movements required for PA and sports can expect to be hindered. Subsequently reducing lifelong PA engagement.

Collectively, these findings highlight the deficits of locomotor skill development in children from Asian backgrounds and the lack of FMS mastery achievement during MC overall which is poorer in females; all who live in a deprived area in

England. The reduced FMS proficiency of children from Asian backgrounds and middle childhood females along with support from limited previous research (Eyre, Walker and Duncan 2018) infers that they experience greater constraints within the individual, environmental and/or task-dependent domains compared to children of Black and White ethnic backgrounds and their male counterparts (Newell 1986). The proficiency levels of the children may, therefore, be explained. It should be considered that FMS are taught to and practiced by children as a means of development. The provision of PE provided all of the children with the same FMS learning environment. Constraints experienced by Asian children and females may, therefore, sit more within the individual and task domain where FMS are taught in PE. The constraints encountered by children within this specific sample were explored through studies two and three and will be discussed within the following sections.

10.2 **Are there direct relationships between FMS, MVPA, PMC and HRF in primary school children from a deprived and ethnically diverse area? Do PMC and/or HRF measures act as mediators between FMS and MVPA within this sample?** (*Study Two: Section 6.0, question 1 and 2*)

Study Two provided a greater context of findings within the sample from study one by examining the mediating roles of HRF and PMC. Findings showed a consistent association between the FMS (total, object control and locomotor skills) and PMC of children in middle childhood but not in early childhood. Though perceived motor competence was only associated with MVPA in MC where locomotor skills were included in the analysis. As proposed by previous literature, children's ability to accurately assess their actual motor competency increases through cognitive development thus may in part explain the differences shown between these two ages (Stodden et al. 2008, Harter 2015). Direct associations were also found between HRF, FMS and MVPA though these differed between year groups. Associations in MC were greater in number and significance, therefore suggesting that these along with associations found regarding PMC may strengthen with age. Engagement in PA requires the necessary skills and FMS require movement patterns to be correct along with cognitive processing and effective production of force through strength (Moody et al. 2014). Associations in MC can in-part be explained as HRF was a combination of sprint speed, jump distance and strength, components that develop with age (Barber-Westin, Noyes and Galloway 2006, Papaiakovou et al. 2009).

Further exploration of PMC and HRF as mediating mechanisms presented novel results. HRF of children in early and middle childhood accounted for greater variance in comparison to PMC. In addition to this, mediation only occurred through HRF in both early and middle childhood but not PMC. HRF is shown to have a greater bearing on the association between FMS and MVPA, and subsequently children's health trajectories across childhood than PMC. If direct associations between PMC and FMS in this sample only begins to during MC, as previously discussed, it is understandable that mediation did not occur through PMC in either age-group. Therefore, HRF may in-part explain the lack of FMS mastery achievement in study one. Additionally, interventions during early and middle childhood focusing more towards HRF when aiming to improvement FMS and PA may be key in tackling the lack of FMS mastery achievement found in study one.

10.3 **What perceived barriers and facilitators to FMS development, PA engagement and PE are present internally and externally to the school environment?** (*Study Three: Section 7.0, question 1*)

Study Two shows that the individual constraint of HRF had a greater influence on the current FMS proficiency levels compared to PMC, thus having a greater contribution to the currently low FMS proficiency of children in deprived and ethnically diverse areas shown in study one. Subjective context to the low FMS proficiency observed in study one was provided through the qualitative means. The barriers and facilitators of FMS development, PA engagement and PE were identified by teaching staff in study three who were from the primary school samples used in studies one and two.

Environmental and task constraints were identified as staff highlighted a lack of safety in the local area; parents (i.e. lack of priority placed on PA, the local community not viewed as safe and a lack of household finances); as well as lack of PA experiences or exposure outside of school and a crowded primary school curriculum. These barriers were mostly linked to deprivation and ethnicity (e.g. social norms). The facilitator's primary included the school environment (i.e. large spaces, outdoor structures and equipment) staff (i.e. teachers and staff teaching PE/sports) and finally community structures (i.e. parks) although the lack of safety presented in barriers seemed to inhibit the use of these community structures. These findings develop and support that there are increased constraints experienced by children living in deprived and ethnically diverse areas externally to the school environment compared to internally (Roscoe, James and Duncan 2017); which has also been shown in greater amounts of PA being engaged in within the school environment compared to outside (Eyre et al. 2015). This shows that the factors contributing to the current FMS proficiency found in *Study One* are complex, and the ability to overcome barriers may be easier to initially tackle within the school environment. Furthermore, it also shows the importance of the school environment facilitating the improvement of FMS although it does come with its constraints that could be inhibiting a Childs ability to develop skills and be active.

FMS are initially taught within primary schools through PE. However, PE was found to not be prioritised within the curriculum, as there is more emphasis on children being pushed academically in English, Maths and Science. This was mainly attributed to the need to meet assessment requirements set within the schools; guided by policy and regulations determined through governing bodies (e.g. The Department for Education, OFSTED). Alongside this, further influences such as performance-related pay which was introduced in 2014 (Department for Education 2017) are guided by policy and regulations also meant academic achievement overshadowed PE. Furthermore, many teachers also did not feel that they received adequate training for teaching PE and while at work were not currently receiving any form of CDP within the subject. Similar practices within schools and in teacher training for PE have been found in the UK, spanning back over a decade (Boyle and Bragg 2006) (Carney and Armstrong 1996, Harris, Cale and Musson 2012). Teachers, therefore, receive little support, training/experience in school due to PE being delivered up to twice per week. The requirements of FMS being taught may therefore not be provided effectively for children contributing to the lack of mastery achievement as seen in study one. To overcome this, teachers require further training specific to PE and it may also be necessary to utilise those that are qualified to deliver the PE curriculum for greater achievement.

Interventions to improve FMS are often delivered by researchers or specialists within the field, removing the responsibility form the teachers. Many interventions have been proven to be successful and suitable (Heath et al. 2012, Lai et al. 2014) however, the long-term sustainability of this method is questionable. Teachers felt there were both benefits and limitations to PE specialists being employed in schools. They appreciated the ability for PE specialists to maintain a consistent provision of PE and extra-curricular activities which would intern reduce their workload concerning planning as well as delivery. However, the limitations linked greatly with long-term implications. There was a concern that PE may become a specialist subject as well as compromising the delivery and achievement of the PE curriculum aims, thus further inhibiting children's engagement with PA and subsequently development and practice of FMS, which may further regress the already delayed achievement of expected FMS proficiency levels. Recommendations to embrace the benefits and overcome the limitations included utilising specialists/coaches occasionally throughout the academic year to help assess progression, direct the PE content for future weeks, enable teachers to observe and lead afterschool clubs/activities.

Study Three showed several constraints relating to FMS development, PA engagement and PE perceived by primary school teaching staff. Considering Newell's constraints theory (Newell 1986) tackling the lack of mastery achievement at a school level was proposed to initially be most effective through adapting the current content and delivery of PE; subsequently, improving FMS through attempting to remove constraints that negatively impact the teaching and learning of FMS. Key elements that were considered, particularly to inform study four were focused around provoking minimal disruption to the already crowded curriculum, not imposing increased workloads on teachers and providing teachers with the opportunity to observe PE delivery. Identifying constraints through study three, combined with the influence of HRF found in study two enabled a more specific approach to tackling the reduced mastery achievement observed in study one.

10.4 Is it possible to improve FMS mastery attainment levels in multi-ethnic groups of children living in a deprived area in England through the adaptation of PE delivery? (*Study Four: Section 8.0, question 1*)

Through *Study Four* combining one INT and one statutory PE resulted in improvements in total FMS; specifically, locomotor skills across six weeks, as well as sustaining sprint speed improvements six weeks beyond the intervention during MC. The prescription, duration and content of the sessions addressed constraints within the individual, task and environmental domains; guided by the lack of FMS proficiency achievement observed within study one, the associations between HRF and FMS observed in study two as well as previous research (Faigenbaum et al. 2011, Duncan, Eyre and Oxford 2017). However, the effectiveness of this intervention compared to standalone PE requires further investigation within this sample.

Study Three identified constraints within the primary school environment which informed the following elements within this intervention:

1. The intervention was implemented during the weeks with the least extracurricular activities scheduled to occur in the school halls. Prior to sessions hall bookings were always checked with the class teacher as well as the reception team at the school as teaching staff identified that double bookings often meant that PE lessons were cancelled/rescheduled.

2. The Principle investigator delivered the intervention to ensure scientific rigour and consistency as training was not provided to teachers. However, this also tackled the limited time teachers have to prepare PE lessons, challenges with session content (progressions/regressions) as well as the consistency in the delivery of PE due to experience/confidence of staff.

3. Teachers were encouraged to observe freely and assist with behaviour management when necessary during sessions. Although this was not directly assessed and reviewed, teachers expressed their desire to engage in CPD through shadowing. As such the opportunity was afforded to them indirectly through the intervention.

Collectively, this study supports Newell's constraints theory (Newell 1986), where identifying and changing constraints encountered by the individual (Children in middle childhood/teachers), the task (developing FMS/PE delivery) and within the environment (primary schools), can positively influence outcomes. In this case, incorporating INT into the PE curriculum is beneficial for the improvement of locomotor skills and sprint speed during middle childhood in the sample of children living in a deprived and ethnically diverse area in England. However, significant improvements in object control skills did not occur. Focus is therefore required on ways to improve this subtest which may be combined with INT, developing a more effective PE programme. As FMS mastery attainment during middle childhood and proficiency development during early childhood is not as expected within such a sample, identifying successful ways to overcome constraints and subsequently improve deficits is important. Where FMS proficiency improves there is greater scope for more complex skills required for PA engagement to improve (Logan et al., 2018), positively impacting on life-long health through greater engagement in PA (Janssen and LeBlanc 2010). The positive impact the intervention provided, along with the practical viability of INT within the school environment in England and the curriculum shows the potential benefit of integrating such a training method into the PE curriculum in England to enhance the development of FMS. Due to the sample size of the study future work should aim to assess the intervention on a wider scale (e.g. Multiple schools), adapting the limitations, to further explore the limited findings within such a unique population and environment.

10.5 Novel contributions to the literature

The findings of the thesis make novel contributions to the literature. Firstly, the thesis shows that there are deficits in the FMS developmental expectations of these children during acquisition and mastery, particularly those of Asian ethnic backgrounds. Children in the critical developmental stages of FMS (early and middle childhood), within a deprived population in England that is ethnically diverse have rarely been observed. The ethnicity of participants is often not reported in demographics or considered when data is analysed with only one other study conducted in England observing FMS in relation to ethnicity during early childhood (Eyre, Walker and Duncan 2018). There is, therefore, a need for further investigation into the current state of children living in areas that are ethnically diverse and classified as deprived.

Novel contributions are also presented in the thesis in that HRF may hold greater weight in FMS development from as early as four-years-old. The proposed variation in the association between FMS and PA through PMC may occur beyond ten-years-old, if at all in children in a deprived and ethnically diverse area. Associations were shown with HRF and FMS in early and middle childhood as well as HRF mediating the relationship between FMS and PMC in both age groups. Furthermore, direct associations were only found between PMC and FMS during middle childhood with no mediation present. As this was the first study to assess the Stodden model (Stodden et al. 2008) in full and within this population, further research should be conducted to further develop findings.

The thesis also provides a novel perspective from teaching staff of the barriers and facilitators to the FMS development, PA engagement and PE delivery/planning, experienced by children during early and middle childhood living and attending schools located in a deprived and ethnically diverse area in England. Previous research had only been conducted with teachers in a preschool setting (Roscoe, James and Duncan 2017) and parents (Trigwell et al. 2015, Eyre et al. 2017). Thus the thesis explores a unique first-hand perspective, specifically on the school environment which was unable to be provided by preschool staff where the aims, structure and prescription of PE different (DfE 2014, 2017) or parents who do not work within a primary school. Additionally, constraints were able to be identified in the context of the reality of the school environment; not only experienced by the children in FMS development and PA engagement but also by the teaching staff involved in facilitating the development of these.

Lastly, this was the first study to integrate Integrative Neuro Muscular Training into the PE curriculum to develop process and product FMS in nine-to-ten-year-olds. Previous findings show that Integrative Neuromuscular Training carried out before PE lessons and integrated into the curriculum has improved FMS and strength measures in children aged five-to-eight-years-old (Faigenbaum et al. 2011, Duncan, Eyre, Oxford 2017). Progression of the research was made with the thesis showing success in nine-to-ten-year-olds; improving but not completely eradicating the deficits in FMS mastery attainment. Furthermore, the intervention showed success within the parameters of the current curriculum structure by being conducted on the primary school grounds over six weeks within PE lessons. As a result, no additional disruption was caused to the average school day whilst also ensuring PE is delivered during the designated time.

10.6 Strengths

The thesis held strengths in explorations of the theory and methodological approaches. Firstly, the thesis explored FMS of children in early and middle childhood in Coventry; a deprived area in England that is ethnically diverse. Though the literature has briefly explored FMS and deprivation in the UK, minimal research has considered the ethnic backgrounds of participants within the analysis. A focus on deprivation and ethnicity was crucial to the FMS research base, particularly as previous findings promote the relationship between FMS and PA, the inverse relationship between weight status and FMS, as well as lower PA engagement levels and higher weight status' children living in, deprive areas and those of BAME backgrounds (Eyre et al., 2013; Falconer et al., 2014; Lopes et al., 2011; Robinson et al., 2015). This thesis identified FMS proficiency of children in deprivation as well as provided insight into ethnic variations.

To carry out this research, quantitative and qualitative approaches were employed to explore FMS proficiency as well as the factors influencing proficiency. Concerning FMS proficiency, utilising both methods enabled analysis of the quality of movement within the sample as well as product outcomes. This provided a greater depth of understanding of proficiency within and between males and females in early and middle childhood from Asian, Black and White ethnic backgrounds, in comparison to using solely one method. Further to this, utilising both approaches enabled the thesis to collectively assess and identify objective and subjective contributors to the FMS proficiency levels specific to the sample that was ethnically diverse, living and attending schools in a deprived area in England. This enabled a more comprehensive and direct insight into the complex combination of mechanisms that are contributing to the initial findings; subsequently, providing a better understanding of ways to approach improving the current proficiency levels.

The quantitative exploration of mechanisms used within this thesis was based on Stodden's theoretical model (Stodden et al. 2008). This model has been cited in over 1000 articles and viewed over 6000 times since its publication in 2008. It is based on a wide range of literature and was also reviewed in 2015 (Robinson et al. 2015) to consolidate the supporting evidence, yet the model itself has scarcely been assessed in its entirety with all factors taken into account. This thesis analysed the model in full, considering direct and indirect associations between FMS, PA, HRF and PMC and was the first to conduct this analysis in a multi-ethnic sample of children during both early and middle childhood that live in a deprived area, that is difficult to reach.

Finally, this thesis developed a pragmatic intervention for use in primary schools that is effective through being guided and informed by previous interventions. As well as the lack of mastery achievement observed during middle childhood in *Study One*, the variance accounted for by HRF in *Study Two*, along with the in-depth findings relating to the topic areas explored in *Study Three*. Collectively, this information influenced one of the first Integrative Neuromuscular Training programmes to be incorporated into the PE curriculum in England within a sample of ethnically diverse children during MC. The programme considered the previous application of the type of training as well as the realities within the environment it was being employed in and the specific needs of the sample.

10.7 Limitations

The thesis focuses on a novel research area which develops the current findings but is not exempt from limitations. Attaining PA data from children is challenging due to multiple issues with compliance (Hildebrand et al. 2014). Although issues were considered within the thesis (e.g. wrist-worn monitors, fitting monitors for 7 days; (Nyberg et al. 2009, Hinkley et al. 2012) the sample size of *Study Two* and the inclusion of PA data in study four were both severely inhibited by a lack of compliance which led to a lack of valid data (≥4 days; 10 hours per day). Compliance within the thesis was not directly assessed but children often commented that they had forgotten to replace the device in numerous circumstances including after taking a bath or swimming; taken it off when they were sleeping and left it a home; removed it when playing football because they did not want to break it. A total of 191 children (early childhood; 108, and middle childhood; 142) and 44 children were initially provided with PA monitors for *Study Two* and *Four*, respectively. Due to a lack of valid PA data, just under half of the participants were removed from *Study Two* and PA data was not included in the analysis of *Study Four*; severely reducing sample sizes.

Justification for accelerometers being positioned on the wrist is outlined in detail within *section 4.2.4.2*. While locating devices on the wrist improves the ability to capture PA involving the upper-body such as in object-control skills, there is limited ability to differentiate between the types of skills engaged in at any time. The criterion method to attain this data would be to employ direct observation, however, as previously discussed due to the nature of the study and sample size this method was not a pragmatic method to collect PA data within the thesis (*Table 4.6.* Sirard and Pate 2001, Vanhees et al. 2005, Hills et al. 2014, Sylvia et al. 2014).

The cut-points used to establish PA intensity through wrist-worn accelerometers is limited as the majority have been established where devices are worn on the hip (*see section 4.2.4.4.*) even though wrist-worn devices hold greater compliance and are more practical in the child population (Hildebrand et al. 2014). The cut-points used within the current study, were valid, reliable and age-specific to the sample (Johansson et al. 2015, Crouter et al. 2015) however the use of cut-points to determine PA intensities has its challenges.

Exploration of wrist-worn cut-points would support findings as well as utilising a more practical method of assessing PA intensities engaged in by children (*see section 4.2.4.2*). Furthermore, the identification of cut-points to establish PA intensity levels is valid showing sufficient sensitivity and specificity (Migueles et al. 2017) however, the ranges set to define intensities are broad and may prove to be problematic for those that sit on the borderlines. For example, children during early childhood would be identified as engaging in sedentary PA if their vector magnitude reading was ≤221, low intensity between 222-729 but high if this reading was ≥730 (Johansson et al. 2015). Children therefore firstly, who reach a vector magnitude of 222, just missing the classification for *sedentary PA*, and those who reach 729, just missing the classification for *high PA*, are both being identified as engaging in *low* levels of PA. This is important for example where children are being classified as meeting the UK recommendations for PA engagement to establish prevalence or observations of post interventions.

The assessment of FMS was conducted using the valid, reliable and widely used TGMD-2 process-oriented tool. Due to the focus within the PE primary school curriculum in England, not all skills were included in the subtests of Object control and Locomotor skills. Utilising raw scores instead of the classifications established using norm data based on an American population, provides outcomes that are not skewed by the proposed differences between countries (Bardid et al. 2015, 2016). The selection of specific skills, however, reduces the ability to compare overall results of Total FMS, object control skills and locomotor skills broadly with the literature.

Study Four included an intervention and control group from two different schools in Coventry. It was therefore not possible for the sample to have been randomised which may incur some systematic bias within the study. However, both groups were in the same school year, attending schools in Coventry; an area of deprivation and did not present and significant differences in measures at baseline which was favourable. The PE curriculum in England is not delivered uniformly across the academic year (e.g. term 1; basketball, term 2; gymnastics etc.) as teaching staff will meet the curriculum through various activities that they are confident with and classes with PE specialists vary between schools. Therefore, there was no way of controlling the content undertaken by the control or intervention group within their second PE sessions, or using an additional control and treatment group. Future interventions may benefit from utilising randomised samples within the same school while being cautious of interactions between the groups if participants are in the same classes. Furthermore, using participants from the same schools can help to reduce variances in additional activities engaged in between the two groups, enabling for greater control.

11.0 FUTURE DIRECTION OF RESEARCH

The thesis provides novel insight into the current state of FMS proficiency in a sample of children living in a deprived and ethnically diverse area; as well as a comprehensive understanding of contributing influencers and a practically viable way to challenge constraints, improving proficiency. Findings make an important contribution to the research however; previous research needs to be considered in the generalisability of findings. Previous findings have shown variance in FMS proficiency between children living in areas with differing degrees of deprivation (Morley et al. 2015), as well as between children of different countries (Bardid et al. 2015). As such further exploration of FMS proficiency in children living in England, the UK and internationally in other deprived and affluent areas that are not ethnically diverse, as well as deprived and affluent areas that are ethnically diverse to broaden the scope of the thesis. Additionally, investigating the influencers of the prevalence found within these areas would enable findings to be specifically contextualised to the samples, comparisons to be made with greater understanding and a more informed idea of generalisability of findings.

It is clear that children that are living in deprivation as well as ethnically diverse areas are not acquiring skills adequately during early childhood and are delayed in their development of these skills as they are not mastering them as expected during middle childhood. However, there is little understanding of FMS proficiency in-between these time points. Future research should aim to establish prevalence in the years between these critical periods of development, providing a more in-depth picture of FMS prevalence of children in deprived and ethnically diverse areas across developmental time.

Interventions to improve FMS of children within these groups are necessary overall, attention should be placed on children from Asian backgrounds as well as females in middle childhood. These specific demographics exhibit the worst skill levels, suggesting that they are at the greatest risk of not having the sufficient ability to engage in PA. Furthermore, PA data shows that females and children from Asian backgrounds engage in the least amount of PA (Eyre et al. 2013, Townsend et al. 2015). Further research should look do develop the findings of this thesis by identifying constraints that are specific to these two demographics as well as working towards tailored interventions to help reduce the proficiency gap.

Considering the influence of HRF as a measure of sprint speed, jump distance and handgrip strength, on the relationship between FMS and PA is shown from as early as four-years-old. It is therefore vital that this mechanism is explored further within interventions to reduce the potential negative impact of the constraint which sits within the 'individual' domain on FMS development.

Further progression of the research would be gained by tackling the apparent teacher training deficits in England as well as incorporating teaching staff in the delivery of interventions to provide sustainable models. It may be that interventions that successfully improve FMS are observed and then re-administered by teachers after undertaking the necessary training for delivery.

This would enable FMS proficiency to be addressed, the current insufficient teacher training and the implementation of a sustainable method. Due to the uniqueness of children and their development, although the fundamental underpinning of the intervention should be generalised much like the PE curriculum, approaches may need to be school-specific ensuring that FMS proficiency is first assessed along with the constraints encountered by children and teachers in the planning and delivery of the PE curriculum.

Many of the barriers to PA and FMS development were identified outside of the school environment. On a wider scale, incorporating parents in the pursuit of improving FMS may be pivotal as they were identified as a primary barrier. A direct approach may be in changing their perceptions of the importance of PA through education. Indirectly strategies such as providing free and/or more affordable programmes for children would circumvent the financial challenges described. All approaches with parents should consider cultural norms/expectations, as these were perceived to influence the low priority they placed on PA as well as their willingness to allow their children to engage in PA within their neighbourhoods.

12.0 GENERAL CONCLUSION

This thesis presents the disproportionate development of FMS in children from a deprived area in England between and within different ages, sexes, and ethnic backgrounds. Removing constraints experienced by these children can improve FMS proficiency. The mechanism of HRF was shown to have a greater influence on associations between FMS performance and PA engagement compared to PMC from as early as four-years-old. It is also suggested that PMC within this sample may influence that association between FMS and PA latter than previously presented within the literature, thus attempts to improve FMS and PA may find greater benefit from improvements in HRF compared to PMC during childhood. Furthermore, the school environment seems to be the most facilitative environment to improve FMS once barriers such as teacher training, delivery and planning are tackled. Greater improvements may be achieved through addressing additional barriers identified (e.g. the priority of English, maths and science). Changing such barriers however face the biggest challenge and maybe more complex considering that they are heavily influenced by external bodies, some of which sit at government level. Effort in tackling the complex barriers external to the school environment with multiple components (local community and the home) should not be ruled out; greater exploration is needed to provide a direct and more in-depth insight. This would inform approaches in overcoming constraints which may need to be considered in conjunction with each other at a government/council level (e.g. local council initiatives to improve area safety) as well as within the home (e.g. educating parents about life-long benefits of PA).

13.0 PRACTICAL APPLICATION

In England, children living in areas that are deprived and ethnically diverse engage in the lowest amounts of the recommended PA (duration and intensity) (Eyre et al. 2013, Falconer et al. 2014), and present with the highest risks to health that are related to insufficient PA engagement. This thesis shows that children during early and middle childhood within these demographics also demonstrate low proficiency of FMS that is required for PA engagement. The integration of INT into the primary PE curriculum in England, while considering the constraints within this environment, can improve FMS. The intervention employed is suggested to be more favourable to the development of locomotor skills and sprint speed; hence the recommendation to integrate INT into the PE curriculum. Identifying ways to adapt the programme to promote improvements in object control skills and a greater amount of HRF measures is therefore important. Improved proficiency of FMS will provide these children with a greater ability to engage in PA and subsequently reduce health risks that will benefit them into their adult lives (Stodden et al. 2008, Robinson et al. 2015).

14.0 APPENDICES

Appendix 9.1. Integrative Neuromuscular Training programme

	Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**
Warm up (~5 mins)	Squats x 10 Bear Crawl F x 3 (5m) Sticky Feet x 5 R/L	Squats x 10 Bear Crawl Fx3 (5m) Sticky Feet x 5 R/L Numbers and Body Parts (No. & BP)	Squats x 5 Bear Crawl Fx2 (5m) Bx2 (5m) Sticky Feet x 5 R/L No. & BP	Squats x 5 Bear Crawl Fx2 (5m) Bx2 (5m) Sticky Feet x 5 R/L No. & BP	Squats x 5 Bear Crawl Fx2 (5m) Bx2 (5m) Lx2 (5m) Sticky Feet x 5 R/L	Squats x 5 Bear Crawl Fx2 (5m) Bx2 (5m) Lx2 (5m) Sticky Feet x 5 R/L
Main Session ~40 mins **Week 1-2 Instruction time per exercise: ~1-2mins** **Week 3-6 Instruction time per exercise: ~0.30 – 1 min** **Weight: 2kg Sandbell 1kg Med ball**	Circuit Station (x2) **1.** Pairs 4x3 **2.** Balance it 4x3 Move your feet **1.** Double steps FWD Side steps RTN (*2 feet per gap*) **2.** Single steps FWD Side steps RTN **3.** 2 foot jumps FWD 2 foot jumps RTN Games **1.** Walk FWD with bean bag on head (BB), Side step RTN with BB, 3 med ball throws.	Right side up *A – 8 cones (C)* **1.** Run **2.** Gallop **3.** Hop *B – 2 cones throw BB into hoop* **1.** Run **2.** Sticky feet Monkey Business **1.** Gorilla Walk with squat (L&R) **2.** Gorilla walk with squat sandbell (SB) throw ↑ (L&R) **3.** Gorilla walk with squat SB throw → (L&R)	Move your feet (Ladders) **1.** Single steps **2.** Jump **3.** step FWD Side jump RTN **4.** jump FWD Side step RTN Circuit Station (x2) **1.**Pairs with BB - walking forwards 3 passes x3 -walk across bench with BB on head **2.** Balance it (BB on head) - walking pass forwards	Right side up *A – 8 cones* **1.** Run **2.** Bunny Hop **3.** Hop *B – 4 cones throw BB or MB into hoop* **1.** Run / BB **2.** bunny hop / MB **3.** Sticky feet / MB Monkey Business **1.** Gorilla Walk with squat (L&R) **2.** Gorilla walk with squat SB throw ↑ (L&R)	Circuit Station (x2) **1.** Balance it – Overarm throw @ wall target x2 **2.** Balance it – Underarm throw @ floor target x2 Pairs with MB **1.** Forwards – 3 passes x3 **2.** Lateral – 3 passes x3 Move your feet **1.** Double steps FWD jump RTN (*2 feet per gap*) **2.** Single steps LAT Jump RTN **3.** 2 foot jumps in & out FWD & RTN	Olympics **1.** Bench walk with BB on head. Throw BB overarm at wall target. **2.** Gorilla walking. Squat down throw SB forwards into hoop. **3.** 3 MB passes. 2-footed jumps forward in speed ladder. MB underarm throw at wall target. **4.** Right side up (x8 C). Squat down toss SB as high as possible. *A.* 2-footed jumps over low hurdles (x5). MB throw (x4). Walk over upturned bench

	2. Run FWD, Skip RTN, 3 med ball (MB) throws **3.** Skip FWD, Skip RTN **4.** Hop R FWN, Hop L RTN		- walking pass side to side Games (x2) **1.** Walk across bench, squat down and throw SB **2.** jump over 6 low hurdle and throw MB into hoop	**3.** Gorilla walk with squat SB throw → (L&R)	Games (course) **-**Right side up (3 cones) -Run -Jumps (5 hurdles) -Underarm throw with BB into hoop	with BB on head. Throw BB into floor target zone. *B*. Right side up (x6 C). 4x MB throw. 2-footed jumps ladders. Throw BB into floor target zone.
Cool Down (~5 mins)	No. & BP	No. & BP	No. & BP	No. & BP	No. & BP	No. & BP

Appendix 10.1 Test of Gross Motor Development 2 scoring criteria (adapted from (Ulrich 2000).

Content removed on data protection grounds

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