Developing a school-based universal screening tool to identify deficits in fundamental movement skills in children aged 5-11 years

Lucy Hannah Eddy

Submitted in accordance with the requirements for the degree of Doctor of Philosophy

The University of Leeds
School of Psychology

September 2021

The candidate confirms that the work submitted is her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

The data presented in **Chapter 2** has been accepted for publication:

Eddy, L. H., Bingham, D. D., Crossley, K. L., Shahid, N. F., Ellingham-Khan, M., Otteslev, A., ... & Hill, L. J. B. (2020). The validity and reliability of observational assessment tools available to measure fundamental movement skills in school-age children: A systematic review. *PloS one*, *15*(8), e0237919.

The data presented in **Chapter 3** has been accepted for publication:

Eddy, L. H., Hill, L. J. B., Mon-Williams, M., Preston, N., Daly-Smith, A., Medd, G., & Bingham, D. D. (2021). Fundamental movement skills and their assessment in primary schools from the perspective of teachers. *Measurement in Physical Education and Exercise Science*, *25*(3), 236-249.

The data presented in **Chapter 4** has been accepted for publication:

Eddy, L. H., Preston, N., Mon-Williams, M., Bingham, D. D., Atkinson, J. M., Ellingham-Khan, M., Otteslev, A., & Hill, L. J. B. (2021). Developing and validating a school-based screening tool of Fundamental Movement Skills (FUNMOVES) using Rasch analysis. *PloS one*, *16*(4), e0250002.

Only material produced by Lucy Hannah Eddy has been included in this thesis.

Acknowledgements

Firstly, I would like to express my sincere gratitude to my supervisors, Dr Liam Hill, Dr Daniel Bingham and Professor Mark Mon-Williams for their unwavering support, guidance and expertise throughout my PhD. My thanks go to Liam for nurturing my interest in motor development and for imparting his wealth of knowledge on research methods and statistical analysis. He was also brilliant at being 'the voice of reason' when our ideas got a bit out of hand! Daniel has provided a different outlook on this project throughout which has been very useful. His expertise in physical activity and movement behaviours has allowed me to explore new literature and enabled me to utilise behaviour change models to provide a more comprehensive understanding of barriers and facilitators to research in schools. Thank you to Mark, whose third year undergraduate module on motor learning inspired me to do a PhD in the first place! He has been supportive throughout and has provided me with opportunities to engage and work with a range of key stakeholders outside of academia, such as the Department for Education, which has been invaluable not only for this project, but also my professional development.

I would also like to give a special mention to Dr Nick Preston and Jo Atkinson, whose healthcare expertise were instrumental to the success of this project. Their insight on the measurement of motor skills in a clinical setting was central to guiding the development of FUNMOVES. In particular, Nick has been a great mentor to me and I really appreciate all the words of wisdom he has given me throughout my PhD! Perhaps my biggest thank you goes to the schools in Bradford and the children and teachers that participated in this research, without whom this project would not have been possible. Thanks are also due to the BiB staff and CAER interns (Nishaat Shahid, Kirsty Crossley, Marsha Ellingham-Khan and Ava Otteslev) who have helped me throughout with data collection and screening for the systematic review in Chapter 2. On a similar note I am grateful to have been a part of the Born in Bradford and Centre for Applied Education Research 'families', which I have learnt so much from.

I have been lucky enough to make lifelong friends during my PhD, whose support has helped me through the tough times! There aren't enough words to express how thankful I am to Alice, she has been an incredible friend and colleague over the last four years and I am so grateful to have met her. Having started her PhD two years before me, Amy had always been able to provide excellent advice - a lot of the time over cake which is always a bonus! To Megan, I am grateful to have had someone to go on this PhD journey with, experiencing the highs and lows together. I am also thankful to Anna, who has always been free to chat about PhD work and next steps! Finally, I have only had the pleasure of knowing Shania for a year but her bubbly personality never fails to cheer me up; she has been a wonderful source of support.

Last but certainly not least, I would like to thank my family. To my parents who have been incredibly supportive throughout; thank you for reading my drafts in first year when I was too nervous to send them straight to my supervisors! Thank you to my mum for being my constant source of inspiration and to my dad for never failing to know how to make me smile (the red wine always helped)! To my brother Jack, who despite not really understanding my research has always supported my endeavours. Finally, I will forever be grateful to Andy for his patience, love and encouragement, and to our dog Otis for the unconditional affection and endless cuddles which got me through the difficult times. Our adventures as a family have kept me sane - I'd be lost without you both!

I would like to dedicate this thesis to my Grandma Barbara, who sadly died in the summer before I handed my thesis in. I hope you are proud, and looking down on me smiling now that I have 'finally' finished with my university studies.

Abstract

A large proportion of children are unable to perform age-appropriate fundamental movement skills (FMS), despite their importance for wide-reaching childhood development outcomes including physical activity, health (physical and mental) and academic achievement. Thus, it is important to assess FMS so that children needing support can be identified in a timely fashion. There is great potential for universal screening of FMS in schools, but it is yet to be implemented within British Primary schools. Chapter 2 utilised a systematic review to understand what assessments are available to measure FMS proficiency in school children and their psychometric properties. Results showed that the most valid and reliable tools were the Movement Assessment Battery for Children (MABC), the Test of Gross Motor Development (TGMD) and the Bruininks-Oseretsky Test of Motor Proficiency (BOT). Chapter 3 sought to understand the barriers and facilitators to school-based FMS assessments, and develop teacher-directed feasibility guidelines. Results showed that the MABC, the TGMD and the BOT do not meet these guidelines and thus a new tool needed to be developed. Chapter 4 outlined the development of FUNMOVES. Across three studies over 1000 children were tested and Rasch analysis and implementation fidelity results were used to modify FUNMOVES after each study. The finalised version of FUNMOVES had good structural validity and made it possible for teachers to screen the FMS ability of a class in under an hour. Chapter 5 outlined a protocol for further validation and acceptability studies which were not implemented due to the Covid-19 pandemic. In summary, there is great potential for benefit from using universal screening to measure FMS ability in schools, including increased teacher awareness and expedited time to assessment and intervention. FUNMOVES has shown promise for use in this context, and whilst further research is required, it shows promise as a tool for identifying developmental delay.

Table of Contents

List of Figures

List of Tables

Abbreviations

A&C	Aiming and Catching Subtest of the Movement Assessment Battery for Children
ADL	Activities of Daily Living
ANOVA	Analysis of Variance
APPG	All Party Parliamentary Group
ASD	Autistic Spectrum Disorder
AST	Athletics Skills Track
BiB	Born in Bradford
BMI	Body Mass Index
BOA	Bradford Opportunity Area
BOT	Bruininks-Oseretsky Test of Motor Proficiency
CAER	Centre for Applied Education Research
CAMSA	Canadian Agility and Movement Skill Assessment
CFA	Confirmatory Factor Analysis
CMSP	Children's Motor Skills Protocol
COM-B	Capability, Opportunity and Motivation Model of Behaviour
COSMIN	Consensus-based Standards for the Selection of health Measurement INstruments
CPD	Continued Professional Development
CTT	Classical Test Theory
D	Dominant
DCD	Developmental Coordination Disorder
DIF	Differential Item Functioning
DV	Dependent Variable
EYFSP	Early Years Foundation Stage Profile
FASD	Foetal Alcohol Spectrum Disorder
FG-COMPASS	Furtado-Gallagher Computerized Observational Movement Pattern Assessment System
FMS	Fundamental Movement Skills

GP	General Practitioner
GSGA	Get Skilled Get Active
ICC	Intraclass Correlation
IMD	Index of Multiple Deprivation
IRT	Item Response Theory
IV	Independent Variable
KS1	Key Stage One
KTK	Körperkoordinationstest für Kinder
MABC	Movement Assessment Battery for Children
MD	Manual Dexterity Subtest of the Movement Assessment Battery for Children
MOT 4-6	Motoriktest für vier- bis sechsjärige Kinder
MVPA	Moderate to Vigorous Physical Activity
ND	Non-Dominant
NHS	National Health Service
OFSTED	Office for Standards in Education, Children's Services and Skills
OR	Odds Ratio
OSU-SIGMA	Ohio State University Scale for intra-Gross Motor Assessment
OT	Occupational Therapist
P.E.	Physical Education
PA	Physical Activity
PDMS	Peabody Developmental Motor Scale
PGMQ	Preschooler Gross Motor Quality Scale
PMC	Perceived Motor Competence
PROSPERO	Prospective Register of Systematic Reviews
PSI	Person Separation Index
SATS	Standard Assessment Tests
SES	Socioeconomic Status

SF	Short Form
SLT	Senior Leadership Team
SPSS	Statistical Package for the Social Sciences
TDF	Theoretical Domains Framework
TGMD	Test of Gross Motor Development
The Alps	Towards Healthy Education and Learning of Playground Skills
UK	United Kingdom
USA	United States of America

Chapter 1
Introduction

Motor skills are involved in a large proportion of daily activities. We need our brain to send signals to the muscles in our body to enable us to complete everyday tasks such as getting dressed and talking to friends. Motor skills are developmental, and allow children to learn about the world around them. One group of motor skills that is thought to be particularly important for children is Fundamental Movement Skills (FMS). FMS are foundational motor skills that, when mastered, give children the best possible opportunity to participate in lifelong physical activity (PA) and sport (Barnett, Stodden, et al., 2016). Historically, FMS comprised two groups of motor skills; Locomotor and Object Control. Locomotor refers to skills which require you to coordinate body parts to move through space, such as running, jumping and hopping. Object control skills are those which involve the manipulation of an object using a body part, for example through throwing and kicking. More recently, a third group of skills, termed Stability, have been recognised as FMS (Rudd et al., 2015). Stability refers to the ability to sense the movement of body parts and make rapid adjustments to compensate for these movements in order to maintain balance. Stability skills can be further sub-categorised as involving either static (e.g. standing on one leg) or dynamic (e.g. walking along a beam) balance (Gallahue et al., 2012).

1.1 FMS and Childhood Development

1.1.1 Physical Activity

One of the most commonly researched associations in relation to FMS is its connections with physical activity. The World Health Organisation defines physical activity as ‘any bodily movement produced by skeletal muscles that requires energy expenditure’ (World Health Organisation, 2020). The current guidelines within the UK suggest that children aged between 5 and 18 years old should be doing at least 60 minutes of moderate-to-vigorous physical activity (MVPA) each day (Department of Health and Social Care, 2019). Recent survey data found that 55.1% of children did not achieve these guidelines between 2019 and 2020 (Sport England, 2021). It is believed that children who establish strong foundations for FMS in early childhood are more likely to have lifelong participation in PA (Sacko, 2020). With research showing that there are fewer children than ever reaching guidelines for PA worldwide (Guthold et al., 2020), it is arguably more important than ever to consider the role FMS may play for participation in physical activity. A number of systematic reviews have evaluated the relationship between FMS and PA, with three out of four reviews finding that most studies report at least one significant positive relationship between FMS and PA in pre-school children (Jones et al., 2020; Logan, Robinson, Getchell, et al., 2014; Xin et al., 2020), as well as primary and secondary school children (Logan, Robinson, Getchell, et al., 2014; Lubans et al., 2010). These reviews postulate that the strength of the relationship between FMS and PA ranges from low to moderate (Logan, Robinson, Getchell, et al., 2014; Lubans et al., 2010; Xin et al., 2020), dependent on the measures used and the analysis undertaken. A meta-analysis on the results of 19 studies showed a small positive associations between FMS and MVPA (r = .2) and for FMS and total PA (r = .2) (Jones et al., 2020). Gender differences in these relationships have also been noted in two systematic reviews, in which correlations were found to be larger for males than females (Logan, Robinson, Getchell, et al., 2014; Xin et al., 2020). Additionally, object control skills were more closely related to PA for boys. The opposite was true for girls with FMS being more strongly associated with locomotor skills (Logan, Robinson, Getchell, et al., 2014). It is, however, noted that there is a lack of research exploring the relationship between stability skills and PA (Xin et al., 2020). Additionally, a recent systematic review with a focus on longitudinal data found that there was no evidence for PA influencing FMS ability, and that there is only limited indeterminate evidence for the inverse (Barnett et al., 2021).

Since the literature search for the most recent systematic review was completed (November 2019), further research has been carried out to explore the relationship between FMS and PA, including two longitudinal studies (Burns et al., 2020; Nilsen et al., 2020), which found conflicting results. Nilsen et al. (2020) measured FMS and PA 6 weeks apart (before and after the school summer break) and found that PA (as measured by accelerometers) at time point one predicted all FMS at follow up but that FMS did not predict later PA, at time point two. Burns et al. (2020) had a longer follow up (2 years) and found the opposite, in which baseline FMS predicted PA (number of steps) at time point two but baseline PA was not predictive of later FMS ability. Cross-sectional studies have also found conflicting results with regards to the types of FMS that are associated with PA, with some studies finding relationships with object control skills (Capio & Eguia, 2020) and others showing associations with locomotor skills (Aadland et al., 2020).

Recent studies may help to explain these differences though. For example, one study (Martins, Clark, et al., 2020) employed a network analysis and found evidence to suggest that these relationships may change with age. Specifically, the study found that at the age of three, both locomotor and object control skills were positively associated with adherence to physical activity guidelines. Later, at four years old, this relationship was weakened but still significant, and then at five years old the relationship became negative with object control skills. A second study found that the strength of the relationship between PA and FMS might depend on the what different physical activities are measured (Wood et al., 2020). Thirdly, research has shown that adherence to all three aspects of 24 hour movement guidelines (sleep, sedentary behaviour and physical activity) may be more important to FMS development than any one aspect alone, such as PA (Kracht et al., 2020; Martins et al., 2021). Meanwhile a final study observed that decisions relating to how data was analysed could prove influential, because within their accelerometry data the strength of the association between FMS and PA was dependent upon whether the data was analysed in raw, normalised or compositional formats (Aadland et al., 2020). In addition to these explanations, it is likely that the wide range of assessment methods used to measure both FMS and PA in these studies may result in slightly different, not directly comparable constructs having been studied.

1.1.1.1 Stodden Model

The Stodden Model (see Figure 1) provides a conceptual framework to understand the relationship between FMS and PA (Stodden et al., 2008). The model suggests that there is a reciprocal and dynamic relationship between FMS and PA, which is mediated by both perceived motor competence (PMC) and health related fitness. Physical activity is then thought to feed into obesity risk, in which children with higher levels of FMS, PA, PMC and health related fitness are more likely to be a healthy weight, which in turn encourages a positive spiral of engagement. On the other hand, children with low levels of FMS, PA, PMC and health related fitness are more likely to be overweight or obese, feeding into a negative spiral of engagement in PA.

It is proposed that the strength of these relationships change throughout child development (Stodden et al., 2008). It is purported that in early childhood, participation in physical activity may drive the development of FMS due to PA promoting neuromotor development (Fisher et al., 2005; Okely et al., 2001). Differences in the home environment such as parental influence and resources available are suggested to be the reason that children’s early motor skills are so variable, and thus why there is only expected to be a weak relationship with PA within the Stodden model during this timeframe (Goodway & Smith, 2005). As children get older, it is claimed that this relationship will strengthen, as an increase in motor ability widens opportunities to participate in PA. Thus, the Stodden model suggests that in middle and late childhood, the direction of the relationship switches, with FMS increasingly influencing participation in PA (Stodden et al., 2008).

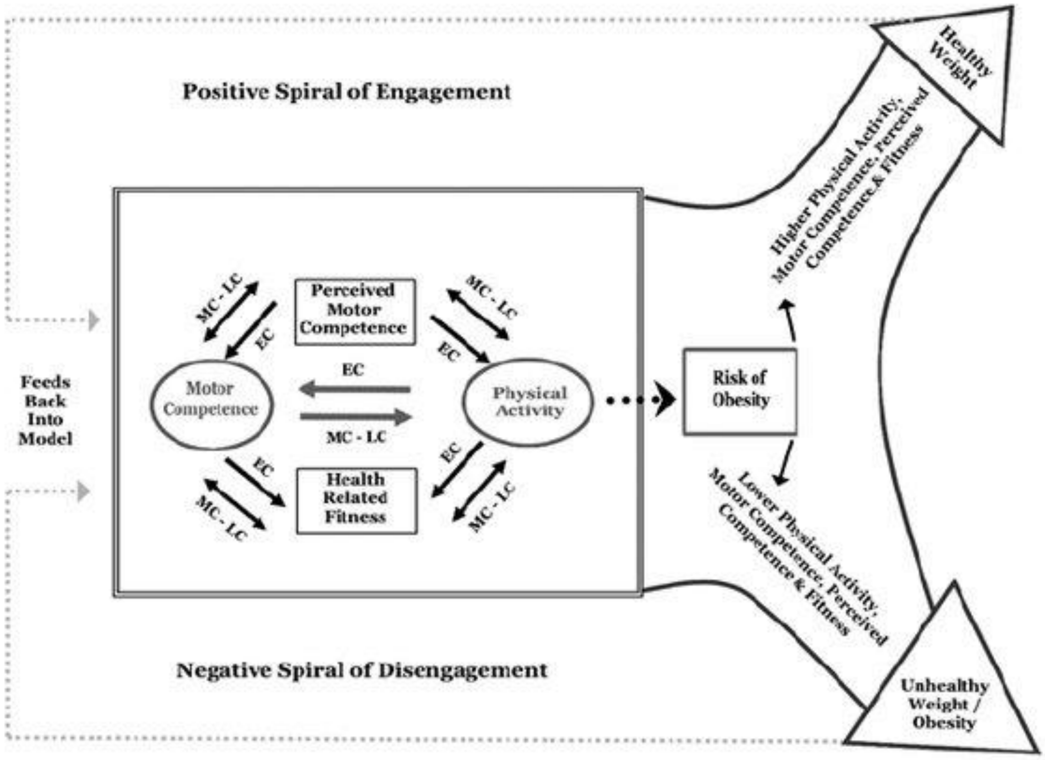


Figure 1 – Stodden Model on the developmental relationship between FMS and Physical Activity

NB: Image taken from Stodden et al (2008). EC = Early Childhood, MC = Middle Childhood and LC = Late Childhood.

1.1.2 Fitness

As mentioned in the previous section, the Stodden model (Stodden et al., 2008) also postulates that there is a relationship between FMS and (health related) fitness. Fitness has been defined as a set of physical attributes which people have or achieve, and include both health-related components (e.g. cardiorespiratory endurance, muscular strength and flexibility) and skill related components (Caspersen et al., 1985). There have been a number of systematic reviews conducted that evaluate this relationship (Barnett et al., 2021; Cattuzzo et al., 2016; Lubans et al., 2010; Utesch et al., 2019), the first of which found that all four studies showed a positive association between FMS ability and fitness level (Lubans et al., 2010). In 2016 the second systematic review included a noticeably increased number of studies (44 compared to four), demonstrating growing interest in the relationship between FMS and fitness (Cattuzzo et al., 2016). When only evaluating studies which had a low risk of bias, there was strong evidence for a positive relationship between FMS and cardiorespiratory and muscle fitness (Cattuzzo et al., 2016). Finally, when utilising meta-analysis to quantify the impact of FMS, the latest review showed moderate effect sizes for FMS' relationship to both physical (r = .41) and cardiovascular fitness (r = .42). The most recent systematic review found insufficient evidence to support fitness impacting upon FMS, but did find strong positive evidence to suggest that locomotor and stability skills have a positive impact upon fitness in childhood (Barnett et al., 2021). In this review, it is also noted that there is strong evidence to suggest that fitness acts as a mediator in the relationship between FMS and PA (which is in line with the Stodden Model). Since the last literature search was completed, studies have continued to find moderate correlations between FMS and both cardiorespiratory (Barnett, Telford, et al., 2019) and cardiovascular fitness (Behan et al., 2020), with one study reporting that 16.5% of the variance in cardiovascular fitness is associated with FMS (Behan et al., 2020).

1.1.3 Weight Status

In addition to fitness, the Stodden model also purports that FMS has an indirect relationship with weight status/risk of obesity, via participation in physical activity. Three systematic reviews have detailed studies on this relationship, all of which found that most studies show an inverse relationship between FMS proficiency and weight status (Barnett et al., 2021; Cattuzzo et al., 2016; Lubans et al., 2010). When focusing on studies with low risk of bias, Cattuzzo et al. (2016) found the number of studies reporting this relationship was higher (eight out of nine studies). More recently, Barnett et al. (2021) found strong evidence of a bi-directional, negative relationship between FMS and weight status. Since this review a number of studies have found that FMS have a significant negative association with BMI and body fat percentage (Behan et al., 2020). Thus, higher FMS ability shows signs of being a protective factor for weight status, even when controlling for potentially confounding demographic factors such as gender and SES (Behan et al., 2020). Research has also shown that Year 1 children's ability to perform some FMS (jump and slide) can predict their BMI one year later, accounting for 12% of the variance (Duncan et al., 2021). Additionally, research has found that 'normal' weight children perform significantly better on tests of FMS children than their overweight and obese peers (Kelly et al., 2019). Some studies have suggested that the relationship between FMS and BMI may depend on the types of FMS measured (e.g.

locomotor skills vs object control skills) but the evidence is mixed with regards to which aspects are comparatively more strongly associated (Draper et al., 2019; Henrique et al., 2020). Lastly, there has been limited research looking at the longitudinal relationship between these skills. However, one study which sampled 2517 primary school children found that higher FMS at baseline negatively predicted BMI at follow up, and that children with higher baseline BMI had lower FMS at follow up (D'Hondt et al., 2014). This is in line with the mechanisms outlined in the Stodden model (Stodden et al., 2008)

1.1.4 Perceived Motor Competence

The final mediator mentioned within the Stodden model (Stodden et al., 2008) is perceived motor competence (PMC). Perceived motor competence can be defined as children’s physical self-concept (De Meester et al., 2020). A recent systematic review and meta-analysis evaluated the findings of 69 studies on the relationship between actual motor competence and PMC (De Meester et al., 2020). It was evident from the meta-analysis, that although a large proportion of the included studies found a relationship between these variables, the effect sizes of these relationships were only small (De Meester et al., 2020). The authors also noted a lack of research conducted to date on the relationship between stability skills and PMC. More recently, Barnett et al. (2021) stated that there is insufficient evidence to support the impact of FMS on PMC, and no evidence on the reverse pathway. They noted 9 studied have explored PMC as a mediator between FMS and PA with results varying dependent on the direction of the pathway. The review showed that there was indeterminate evidence of PMC being a mediator between the relationship between PA and FMS, and no evidence for the reverse. The authors also noted that more work needs to be conducted in this area, as currently there is only inconsistent results from small-scale studies.

1.1.5 Socioemotional Wellbeing

In addition to the factors mentioned within the Stodden model (Stodden et al., 2008), research has also linked FMS to socioemotional wellbeing. Longitudinal research has shown that FMS do not solely impact upon perception of sporting abilities, but also perceptions of physical appearance particularly for girls (Brown & Cairney, 2020). Additionally research has shown that having poor motor skills can be linked to high levels of stress, psychological distress (Li et al., 2019), anxiety and depressive symptoms (Rodriguez et al., 2019) and emotional reactivity (Niemistö et al., 2020; Rodriguez et al., 2019). Low levels of motor proficiency have also been linked to low self-esteem, poor self-concept, and children believing they have less social support (Li et al., 2019) as well as low levels of enjoyment in P.E. lessons (St John et al., 2020). It is, however, important to note that there is a lack of research in this area that uses specific assessments of FMS, instead much of the research uses more general assessments of motor competence (which include fine motor skills) or diagnostic tools for clinically assessing motor difficulties such as Developmental Coordination Disorder (DCD). It is therefore difficult to decipher the specific impact of FMS on socioemotional development beyond PMC.

1.1.6 Academic Achievement

Academic achievement, and the underlying abilities that aid a child's performance in school, have also been linked to FMS within the literature. A recent systematic review looked at the relationships between FMS and scores achieved on measures of reading and maths. It found significant weak to moderate associations with both academic outcomes but with these associations varying depending on the type of FMS measured (Macdonald et al., 2018). In addition, a more recent study by the same author has found significant positive correlations with maths, of a moderate effect size, when using both composite and total motor subscales from the BOT-2 to measure FMS. However, there were no correlations with reading ability (Macdonald et al., 2020). Both longitudinal (De Waal & Pienaar, 2020) and cross sectional (de Waal, 2019) research from South Africa has also found small to moderate correlations between FMS and both reading and maths abilities in primary school children. When looking more broadly at academic achievement, research that evaluated the impact of FMS on a child's average score across all subjects reported that jumping had a significant positive effect for boys; one leg balance had a significant positive effect for girls; and both hopping on one leg and total score had a significant positive effect for both genders (Van Niekerk et al., 2015).

1.1.7 Cognition

There has also been research conducted evaluating the impact of FMS development on a child's cognitive abilities. A systematic review from 2015 revealed evidence for a weak correlation between FMS and crystalised intelligence (van der Fels et al., 2015). There were also correlations found between FMS sub-groups and cognition, in which object control skills were strongly associated with visuospatial working memory, and weakly associated with other aspects of working memory and fluid intelligence (van der Fels et al., 2015). This study also noted weak evidence for there being no relationship between FMS and executive function, attention and general knowledge (van der Fels et al., 2015). It is, however, evident from this review that there was a lack of high quality research in this area.

Studies since the systematic review have found positive associations between FMS and cognitive development in toddlers when controlling for potential confounding demographic factors (Veldman et al., 2019). When looking at pre-school children, research has shown significant positive correlations between both total FMS ability, locomotor ability and all three aspects of executive functions measured (inhibition, attention shifting, and working memory), whilst object control was not associated with attention shifting (Cook et al., 2019). Network analysis has shown weak associations between FMS and executive function (Martins, Bandeira, et al., 2020). Finally, a recent study found that executive function mediates the relationship between FMS and academic attainment, specifically for reading proficiency (Chang & Gu, 2018). It is perhaps unsurprising that these associations are being found considering that the development of both motor and cognitive abilities follow similar timelines (Gabbard, 2011; Gale et al., 2004). Additionally, research has postulated that there is common activation of brain areas, specifically the cerebellum and the prefrontal cortex when completing motor and cognitive tasks (cerebellum & prefrontal cortex) (Diamond, 2000, 2007).

1.2 Current FMS Ability Levels

Due to the importance of FMS for childhood development discussed so far, it is alarming that research suggests a downtrend in the FMS abilities of school-aged children (Brian et al., 2019). Despite a focus on FMS within education in the UK (Department For Education, 2013, 2014), studies consistently find that children are not reaching expected levels. One study which aligned directly with four of the five FMS identified in the Key Stage One (children aged 5-7 years) curriculum (run, jump, hop and catch) (Department For Education, 2013) found that 18.5% of children did not master any of the four skills, and 32.2% only mastered one (Duncan, Roscoe, et al., 2020). None of the children in Year Two (aged 6-7 years old) had reached ‘mastery’ of all four of these skills (Duncan, Roscoe, et al., 2020), despite this expectation being explicitly stated within the national curriculum (Department For Education, 2013).

Additional studies have shown low levels of competence for children in pre-school (Foulkes et al., 2015), Primary School (Farmer et al., 2017; Lawson et al., 2021; Morley et al., 2015; Stratton et al., 2017) and Secondary School (O’Brien et al., 2016) in the UK and Ireland. Reporting of FMS ability varied amongst these samples but the results were consistent in that a large proportion (60%) of children had poor FMS (Stratton et al., 2017) and a small proportion (0% and 11% respectively) of children mastered all of the different types of FMS measured (Lawson et al., 2021; O'Brien et al., 2016). Similar trends are apparent in research worldwide (Ali Brian et al., 2018; Brian et al., 2019; García-Marín et al., 2020; Goodway et al., 2010; Roth et al., 2010; Veldman et al., 2020), with reports ranging between 8.8% (Veldman et al., 2020) and 73% (Brian et al., 2019) of children having low levels of FMS proficiency. This high degree of variation in reported proficiency levels may, in part, be due to differences in the assessment tools used within these studies. Additionally, research has suggested that the force and level of coordination needed to complete each FMS within an assessment may impact upon mastery levels (Lawson et al., 2021).

When focusing on each aspect of FMS development separately, the results are mixed. Three studies conducted in both the USA and the UK revealed that pre-school children performed better on locomotor skills than object control skills (Ali Brian et al., 2018; Brian et al., 2019; Foulkes et al., 2015), however these studies do not report whether these differences were statistically significant. On the other hand, one study found that children performed significantly worse on locomotor skills than object control skills (O'Brien et al., 2016). The sample in this study, was however, older (secondary school) than in the other studies, so it is possible that these differences may be age related. It is also important to note that of all of the studies worldwide on this subject, only three used an assessment tool which included a measure of stability (Roth et al., 2010; Stratton et al., 2017; Veldman et al., 2020). Therefore, it is difficult to ascertain a clear picture of children's balance ability, which has been recognised as an important aspect of FMS (Rudd et al., 2015).

There are a number of factors that have been proposed to have an influence on FMS levels, which are commonly situated within theories of FMS development. Thus, in interpreting and trying to understand the reasons underpinning the current (low) ability levels reported in the extant literature, it is, important to acknowledge both how FMS are developed, and the role that other factors may play in its development.

1.3 Theories of FMS development

FMS are developmental in nature (Gabbard & Rodrigues, 2008), and so improve with age. Numerous theories have been proposed that describe how children develop FMS. These are detailed below.

1.3.1 Mountain of Motor Development

The Mountain of Motor Development (Clark & Metcalfe, 2002) provides a theoretical framework to understand the changes that occur to motor skills from birth, through to the development of FMS (referred to as fundamental motor patterns) all the way to skilful movement (see Figure 2). The first stage of motor development in this framework is the reflexive period, in which two types of movements occur: reflexive and spontaneous. Spontaneous movements occur without the presence of an external stimulus or specific environmental context, for example when an infant’s arm flails. These movements are the opposite of reflexive sensorimotor movements, which are elicited in response to stimuli in the environment, for example sucking or postural changes. The reflexive stage of motor development enables a child to be able to survive and interact with the world (Clark & Metcalfe, 2002). Throughout this period, it is thought that infants learn to assign meaning to movements in relation to their sensory environment (Gibson, 1987).

Infants transition from the reflexive period to the preadapted period where they start to make voluntary movements (Clark & Metcalfe, 2002). In this stage, infants begin to use the sensorimotor patterns learnt during the reflexive period to increase their understanding of how their bodies moves in relation to gravity (Clark, 1994). This includes being able to hold up their own head, support their body and move around (e.g. crawling and eventually independent walking). Additionally, infants begin to gain manipulative skills such as reach to grasp movements (Bushnell, 1985), the refinement of which are aided by improvements in posture (Clark, 1994). Learning how to move through the world and interact with objects ultimately enables an infant to become independent as they can seek out food, and subsequently feed themselves (Clark & Metcalfe, 2002).

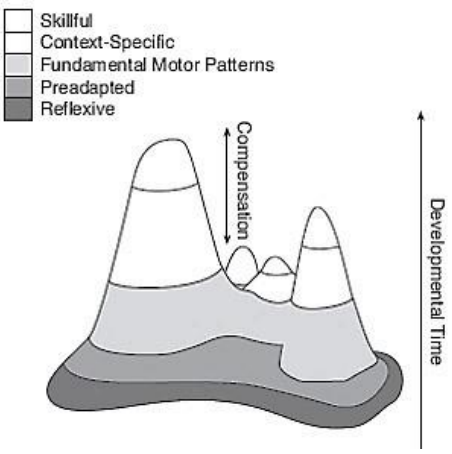


Figure 2 – Diagrammatic representation of the mountain of motor development framework (Clarke & Metcalfe, 2002)

NB: Image taken from Clarke & Metcalfe, 2002.

The third stage of motor development in this framework is the fundamental motor patterns period. During this timeframe, children begin to develop the basic locomotor and object control skills that they gained during the preadapted period to form the “building blocks” for learning more complex, context-specific skills (Clark & Metcalfe, 2002). The mountain of motor development purports that this period lasts until a child is around seven years of age, at which time most children should be able to competently execute such FMS, if given the appropriate environment and opportunities to learn them in early years (Gallahue et al., 2012). Although information is still emerging in this area, with a recent Irish study revealing that FMS improved up until the age of ten (Behan et al., 2019).

After FMS development, children then go on to learn to adapt movements to a variety of specific tasks and environments through the Context Specific and Skilful periods (Clark & Metcalfe, 2002). It is believed that ‘climbing the mountain’ of motor development is a non-linear and self-guided process in which development is sequential and cumulative, resulting in autonomous and adaptive interactions with the environment (Clark & Metcalfe, 2002). The authors note the importance of the interaction between both nature and nurture to influence the development of motor skills at all stages (Clark & Metcalfe, 2002).

1.3.2 Hulteen Model for Lifelong PA

Similarly to the Mountain of Motor Development (Clark & Metcalfe, 2002), Hulteen’s theory (see Figure 3) recognises that children transition from making reflexive to more intentional movements, which are more conducive to becoming self-sufficient (Hulteen, Morgan, et al., 2018). For example, developing crawling and reach to grasp movements, which in combination could be used to gather and eat food. The main difference between these two models is the inclusion of the socio-cultural and geographical filter between Rudimentary Movements and FMS in the Hulteen model (Hulteen, Morgan, et al., 2018). This filter was included because research has acknowledged that motor skills that may be considered ‘fundamental’ in some contexts may not be in others. For example, in the UK, football is a popular sport. Thus kicking may be considered fundamental in this context. However, in countries where playing football is less prevalent, this skill may not be considered ‘fundamental’ to participating in PA. This filter therefore influences the FMS that children are exposed to in different cultures and countries. This model also acknowledges that physical (e.g. weight and fitness) and psychological factors (e.g. self-confidence and perceived motor competence) influence the development of motor skills at each stage (Hulteen, Morgan, et al., 2018).

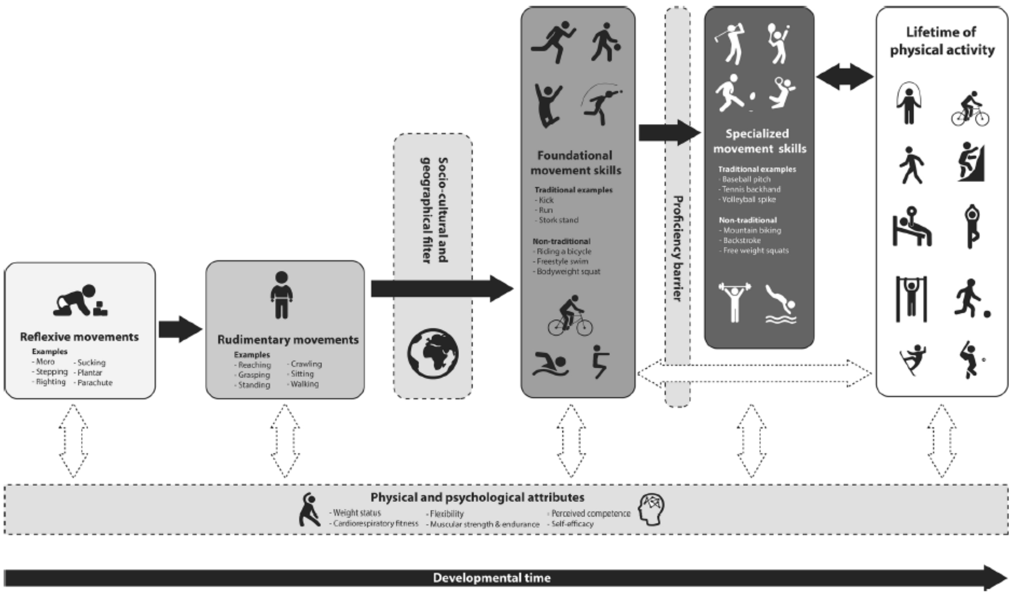


Figure 3 – Development of FMS for participation in lifelong PA model proposed by Hulteen et al. (2018)

NB: Figure taken from Hulteen et al. (2018)

1.3.3 Theory of Constraints

Similarly, the theory of constraints (Newell, 1986) acknowledges the role of external factors in the development of FMS. Newell (1986) proposed a set of three factors that interact to either limit or encourage the development of FMS (see Figure 4).

Individual constraints refer to restrictions brought about by the child that comprise both structural and functional factors. Structural factors relate to the biological makeup of a child that include: height, weight, limb length, and strength. Functional factors refer to psychological constraints, including fear, perceived competence and self-esteem, as well as processes central to successful movement, including vision and other forms of perception (Newell, 1986).

Environmental constraints refer to factors in the setting in which FMS are being performed that may have an impact on proficiency. For example, the surface, the weather, sociocultural influences, lighting, and noise. Task constraints are specific to the activity being undertaken and include the goal of the activity, any rules that define whether a movement is deemed successful, and the equipment being used (Newell, 1986). It is believed that an interaction between these three constraints can have an impact upon how able a child is to coordinate movement. Research has supported this notion, as it has been found that children need to be given the opportunity to learn FMS in formative years in a variety of environments (Gallahue et al., 2012).

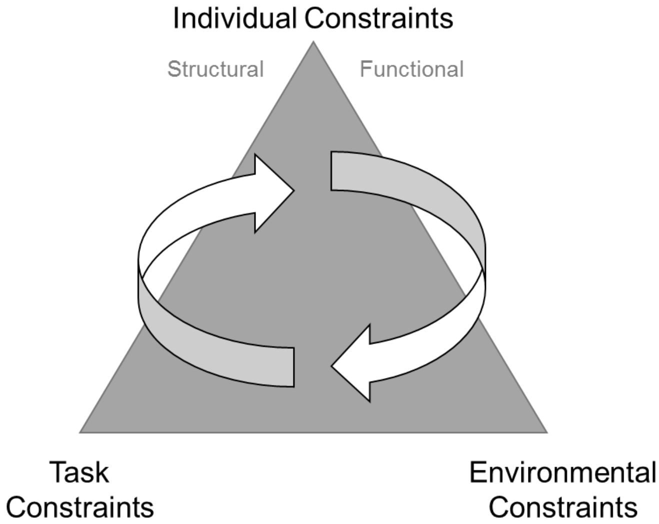


Figure 4 – Diagrammatic representation of the theory of constraints (Newell, 1986)

NB: Figure was recreated from the original figure (Newell, 1986)

1.4 External Factors Influence on FMS Development

As alluded to in the developmental models of FMS discussed in the previous section, there are many factors that are thought to have an influence on FMS proficiency, those most commonly studied are discussed below.

1.4.1 Gender

There is an increasing amount of research exploring the influence of gender on FMS development. When looking at overall FMS ability, the research is inconsistent. Research on pre-school children (aged 4-5 years old) found no difference in total FMS ability between boys and girls (Kokštejn et al., 2017). However this study measured total motor ability (including fine motor skills), rather than specifically FMS, which may have influenced the results. Additionally, it may be the case that differences in total FMS ability may occur as a product of age. Research with primary school children (aged 5-11 years old) has consistently found gender differences, albeit with disparities in findings about whether boys (Adeyemi-Walker et al., 2018; Eyre et al., 2018; Kelly et al., 2019; Morley et al., 2015) or girls (Matarma et al., 2020; Niemistö et al., 2020) are more proficient.

When evaluating the three component groups of FMS (locomotor, object control and stability) separately, the results are more consistent. The most commonly found effect is with regards to object control skills. Most studies examining this domain find that boys perform better than girls when combining scores of throwing, kicking and catching (Adeyemi-Walker et al., 2018; Barnett, Telford, et al., 2019; Ali Brian et al., 2018; Brian et al., 2019; Capio & Eguia, 2020; Cohen et al., 2014; Eyre et al., 2018; Foulkes et al., 2015; Goodway et al., 2010; Kelly et al., 2019; Lawson et al., 2021; Tomaz et al., 2019). One study found that these object control differences may emerge with age. They found no differences for 3-5 year old children, but that that by the age of six, boys were more proficient (Kokštejn et al., 2017). However, a small number of studies have found that there are no gender differences in object control ability for either pre-school (García-Marín et al., 2020) or primary school aged children (Matarma et al., 2020). With regards to locomotor skills, there is a split in the research with some studies finding that girls outperform boys on locomotor tasks (Behan et al., 2019; Cohen et al., 2014; Lawson et al., 2021; Matarma et al., 2020) but most finding that there is no significant difference between genders for these skills (Ali Brian et al., 2018; Brian et al., 2019; Foulkes et al., 2015; García-Marín et al., 2020; Goodway et al., 2010; Kelly et al., 2019; Tomaz et al., 2019). Lastly, there has been minimal research to date into difference between boys' and girls' performances on balance tasks. Most studies find that boys are less proficient (Behan et al., 2019; Matarma et al., 2020; Mickle et al., 2011), but there is some evidence that these differences may be non-significant in some populations (Kokštejn et al., 2017).

It is important to recognise that all of this research is correlational and therefore causation cannot be inferred. It is perhaps surprising that these differences are being found in pre-school and primary school children because biologically, there isn't much difference between boys and girls that could explain these differences (e.g. strength, and limb length) before puberty (Malina et al., 2004). Considering the Theory of Constraints (Newell, 1986), it could be suggested that individual psychological constraints might account for these differences, such as PMC and self-esteem factors may influence these gender differences. The Participation in Lifelong PA Model (Hulteen, Morgan, et al., 2018) would suggest that these differences are also likely due, in part, to the socio-cultural and geographical filter. Previous studies would support this, as it has been postulated that variances by gender are likely found due to differences in the home environment whilst growing up, such as what children have been exposed to by their family, peers and teachers (Garcia, 1994). There has however been limited research on this area.

1.4.2 Socioeconomic Status

Socioeconomic status (SES) is a measure of a person's combined social and economic position within society (Baker, 2014), which is usually measured by their income, education, neighbourhood levels of deprivation and occupation. Two systematic reviews have been undertaken which looked at correlates of FMS that evaluated the impact of SES (Barnett, Lai, et al., 2016; Venetsanou & Kambas, 2010). The first of these reviews found a consistent relationship between FMS and SES, in which children living in lower SES areas, with less educated parents were more likely to have poorer FMS proficiency (Venetsanou & Kambas, 2010). The second review found more inconsistent evidence in favour of SES having an influence on FMS proficiency. However the overall consensus was that higher SES children, on average, have better locomotor skills and score higher on FMS composite scores (Barnett, Lai, et al., 2016).

Since the completion of the second systematic review, studies in the UK, Australia and Brazil have found SES effects, in which high and middle SES children outperform children from a low SES background (da Rocha Queiroz et al., 2020; Morley et al., 2015; Stratton et al., 2017; Veldman et al., 2020). Studies from the USA and South Africa, however, did not find this (Brian et al., 2019; De Waal & Pienaar, 2020; Tomaz et al., 2019). One study found no influence of SES on either locomotor or object control skills (Brian et al., 2019) and a second found the opposite effect, in which low SES children, from rural locations, had significantly higher FMS composite scores and locomotor subscale scores when compared to high SES children from urban locations (Tomaz et al., 2019).

It is likely that differences in the way that SES are categorised in studies may impact upon results because individual measures (e.g. maternal education) often tap into different aspects of home life and do not encapsulate the complexity of SES as a construct (Kininmonth et al., 2020). It is also important to recognise that all of these studies are cross-sectional. Only one longitudinal study has been done in this area, which found that although SES had a significant impact upon FMS ability at baseline (five years old), SES did not have an impact on FMS ability over time (De Waal & Pienaar, 2020). It has been proposed that SES differences may, in part, occur due to differences in space and resources available in the home environment to practice FMS (Venetsanou & Kambas, 2010). It is also possible that access to provision outside of the home and school environment (e.g. sports clubs) plays a role.

1.4.3 Ethnicity

Studies examining the relationship between ethnicity and FMS have also reported somewhat conflicting results. A systematic review (Barnett, Lai, et al., 2016) found two papers that looked at the correlation between ethnicity and FMS proficiency in childhood, both of which found no association with total motor score (Erwin & Castelli, 2008; McKenzie et al., 2002). These findings have been recently replicated in the USA (Brian et al., 2019). There is, however, a body of evidence which would suggest that ethnicity has the potential to impact upon FMS ability. Studies based in the UK have found that children of South Asian heritage performed significantly worse on locomotor skills and total FMS scores when compared to peers with a White or Black ethnic background (Adeyemi-Walker et al., 2018; Eyre et al., 2018). Similarly, a sample of children in Wales showed that fewer children of Asian descent met expected standards of FMS proficiency than White British children (Stratton et al., 2017). Although UK studies have not found an association between object control skills and ethnicity (Adeyemi-Walker et al., 2018; Eyre et al., 2018), this effect has been found in an Australian sample(Barnett, Telford, et al., 2019). In this study, children who spoke European languages at home scored, on average, two points higher on object control subscales than children who had English as an additional language.

It is likely that the way in which ethnicity is categorised within these studies influences whether or not studies find ethnic differences in FMS ability (which parallels with the issues highlighted with SES in the previous section). Two studies have found different results dependent on the measure of ethnicity, with language spoken at home (Eyre et al., 2018) and the area in which the child resides (Goodway et al., 2010) not demonstrating this relationship but parentally reported ethnicity of the child playing a role in FMS proficiency. It is possible that this is, in part due to the generalisation of ethnicity based on external factors, rather than focusing on the individual child. For example, area lived in may associate with ethnicity due to relationships with ethnic density but area may also be reflective of socioeconomic status. Additionally, it is possible, that for the studies which solely use language spoken at home as the measure of ethnicity (Barnett, Telford, et al., 2019), that the results may reflect the difficulties children with English as an additional language may face in understanding the explanation of activities, and the feedback they are given (Logan et al., 2012). It has also been proposed that differences in FMS ability due to ethnicity may occur due to sociocultural factors such as the importance parents place on physical activity and educational activities (Barnett, Hnatiuk, et al., 2019; Cools et al., 2011) as well as biological factors, such as ethnic differences in BMI and muscle mass (Eyre et al., 2018). Finally, research has found inequalities in the healthcare system for ethnic minorities (Kelly et al., 2016; Nazroo, 2003) which may impact upon the development of FMS for children from South Asian communities.

1.5 Assessment of FMS

As FMS proficiency levels are low worldwide (see Section 1.2), it is crucial that children struggling with their development are able to easily access assessment and intervention services. Currently in the UK, it is necessary for a child to complete a three stage process to receive an assessment for motor difficulties. This process involves: (i) parental/carer identification of an issue, (ii) an appointment with the family's medical doctor/general practitioner (GP) and (iii) referral to an occupational therapist (OT) or physiotherapist, where an assessment can then be undertaken (NHS, 2019). At this appointment, a child is screened for both FMS difficulties, and fine motor difficulties, using the Movement Assessment Battery for Children (Hendersen et al., 2007; Henderson et al., 1992), which requires the child to perform motor skills for the OT that are then evaluated in relation to pre-defined guidance. Only a child who scores below the fifteenth percentile (i.e. they perform worse than 85% of children of the same age, as per the normative dataset for the measure) may be considered eligible for a diagnosis of Developmental Coordination Disorder (DCD), which then enables them to be referred for additional help and support. Whilst it is important to note that a diagnosis of DCD does not rest solely on how a child scores on the MABC (Barnett et al., 2015; Blank et al., 2019), there are, however, often problems at each stage of the process outline above. These problems can result in children with FMS difficulties being missed, and the most disadvantaged children being underserved. The following sections outline the nature of the problems alluded to above.

1.5.1 Problems with Current Assessment Procedures

1.5.1.1 Parental Awareness

Firstly, in order for a child to access an assessment, it requires a parent or guardian to identify that an issue may be present, yet parental estimates of ability may not be accurate. It has been found that a parent's level of knowledge about childhood development can influence their perceptions of their child's ability (Cowen, 2001). Generally amongst parents though, there can be a lack of knowledge about the ages at which children should achieve motor milestones, which leads to parents overestimating their child's ability (Rikhy et al., 2010). This overestimation could lead to children with problems not receiving assessments, and thus not being able to access services to support FMS development. More recently, research has been conducted that compares parental perceptions of motor skills to a child's actual motor competence, as measured by assessment tools. Overall, there seems to be a weak to moderate relationship between parental perceptions of their child's motor ability and the child's actual FMS ability (Brown & Lane, 2014; Estevan et al., 2018; Kennedy et al., 2012; Liong et al., 2015; Maher et al., 2018; Zysset et al., 2018). It is, however, important to note that when more robust statistical tests are utilised, for example, regression, the percentage of the variance that parental perceptions of their child's motor ability accounts for is low (e.g. 6.9% in the Brown & Lane, 2014 study). One study reported that correct identification of ability may also depend on the type of skill assessed, as parents were more accurate for object control skills than locomotor ones (Maher et al., 2018).

In addition, it is possible that gender may have an influence on parental perception of FMS ability, with parents overestimating boys' ability in one study (Estevan et al., 2018). Meanwhile, in a second study perceptions of girls' locomotor ability and boys object control ability being accurate, but not vice versa (Liong et al., 2015). It is also important to note that for three of the six samples detailed above, the parents sampled were from a high SES area, with good levels of education (Kennedy et al., 2012; Liong et al., 2015; Maher et al., 2018), factors that are known to improve the accuracy of parent's perceptions of their child's abilities (Cowen, 2001). Therefore, it is likely that the correlations from these studies may overestimate the strength of relationships in more diverse populations. Due to all of these factors, it is extremely problematic to rely solely on parents or caregivers as a first line of defence in identifying children with difficulties, as it is likely that there will be a large number of children missed.

1.5.1.2 Healthcare Issues

Firstly, the criteria for diagnosing DCD are very stringent. To enable a diagnosis of DCD worldwide a child must meet four criteria outlined by the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2013):

(i) Have motor performance (which is determined by a combined score of both fine and gross motor) below expected levels for their age group
(ii) The motor difficulties in criteria (i) must significantly and persistently interfere with activities of daily living (ADL) or education
(iii) Difficulties must first present themselves in 'early development'

(iv) Children must not have intellectual disabilities, visual impairments or neurological conditions which affect movement

Criteria (ii) is restrictive as ADLs are inherently different to FMS. ADLs refer to the skills a person needs in order to functionally manage basic needs (Mlinac & Feng, 2016), such as going to the toilet, eating, brushing teeth and getting dressed, whereas FMS relate to skills enabling participation in physical activity. Additionally, it is unclear whether FMS difficulties can be classified as interfering with education given that these skills are not measured within the curriculum as a form of academic achievement. Criteria (iii) could potentially exclude children from receiving help if their difficulties with FMS emerged later on in childhood, due to unforeseen circumstances such as the COVID-19 pandemic. This is a plausible scenario given recent research has postulated that lockdown had a negative effect on FMS abilities in Portuguese children (Pombo et al., 2021). Finally, these guidelines preclude children with intellectual disabilities, visual impairments and neurological conditions from accessing support that specifically seeks to improve their motor skills. It is therefore unsurprising that the estimate for the number of children struggling with DCD is a lot lower than the number of children with FMS difficulties. It is estimated that between 2-6% of school-aged children have DCD (American Psychiatric Association, 2013), compared to the studies finding much higher prevalence of FMS difficulties (see Section 1.2).

In addition to this, in recent years there has been severe financial pressure on the National Healthcare Service (NHS) (National Audit Office, 2016), which has only increased due to the COVID-19 pandemic, with reports suggesting a funding gap of around one billion pounds (Mortimer, 2020). With such monetary concerns, it is perhaps unsurprising that there are a number of issues with assessing FMS difficulties through healthcare services. One such issue is higher waiting times. In 2019, a survey of GPs found that, on average, people were having to wait over two weeks (14.8 days) for any appointments which were considered ‘non-urgent’, which includes referrals for motor difficulties. This may, in part, be due to the large number of GP jobs that are unfilled. In 2018 it was reported that 15.3% of GP posts in the UK were unfilled, meaning the NHS had around 6,000 fewer full time doctors than required (Matthews-King, 2018). The same recruitment issues are also apparent within physiotherapy and occupational therapy (OT) services, where there are over 106,000 vacancies being advertised (UNISON, 2019) and upwards of 15% of OT jobs left unfilled (Health Education England, 2017). This subsequently means that fewer practitioners are available to assess children for FMS difficulties. It is therefore, unsurprising, that these teams are unable to meet waiting time targets in the UK (i.e. seeing 90% of patients within four weeks of being referred) (Dunford et al., 2010; Dunford & Richards, 2003). This is evidenced by a survey in Scotland which found that fewer than 50% of patients were being seen in this timeframe within OT and physiotherapy services (Information Services Division Scotland, 2018). This long lead time to assessment (6+ weeks) may be off-putting for parents, particularly if they are unaware of the impact FMS difficulties can have on other aspects of childhood development and wellbeing (Barnett, Stodden, et al., 2016).

Finally, it is also important to note that health inequalities also play a role in whether parents access such services for their child. A longitudinal birth cohort based in Bradford (Raynor & Group, 2008) surveyed over 12,000 mothers and found that low SES mothers were less likely to access primary care services than mothers from high SES when it was not related to their own ill health (Kelly et al., 2016). This may mean that more deprived mothers are less likely to visit their GP for concerns about their child's FMS (Kelly et al., 2016). It has previously been suggested that women living in areas of socioeconomic deprivation find it difficult to access primary care services rapidly when necessary (Smaje & Le Grand, 1997). Kelly et al. (2016) replicated these results, and found the fact that low SES areas have more patients per GP than more affluent areas may contribute to explaining this relationship.

Regardless of the reasons for not accessing primary care services, it is important to acknowledge that these factors have an impact on accessing preventative care. As a result, problems tend to be brought to the attention of healthcare workers in their more 'advanced' stages, particularly in low SES areas (Cookson et al., 2016). This is particularly important in the case of FMS development, as there is thought to be a 'window of development' for these skills (Gabbard & Rodrigues, 2008; Gallahue et al., 2012). In addition to SES, there are also health inequalities in relation to ethnicity, in which ethnic minority groups are less likely to access NHS services than their white British counterparts (Kelly et al., 2016). Research has postulated that this may be due to cultural and language barriers (Szczepura, 2005). This may mean that children from certain ethnic groups could be missed using the current referral system for assessments of FMS issues.

1.5.2 Universal Screening of FMS

Considering the issues with the current system of assessment used within UK, there is a need to explore more resourceful solutions. These could enable improvements in the systematic and efficient assessment of more children's FMS, ensuring that timelier, targeted support can be provided, with greater regularity, and less referral bias. One way this could be achieved is through ‘universal screening’ of children.

1.5.2.1 Potential Role of Schools

In the UK, Primary Schools (children aged 4-11) have previously been identified as an ideal location for such initiatives by the Chief Medical Officer (Finch, 2015). They are a logical place to host universal screening as children spend a large proportion of their time in schools, and early identification of motor skill difficulties is known to be beneficial (Missiuna et al., 2003). Additionally, FMS development is incorporated within the primary school curriculum in the UK. The curriculum for the Early Years (i.e. children aged 4-5 years old) has a focus on the development of FMS (Department For Education, 2014). At the end of this school year teachers are required to rate whether each child is ‘exceeding, ‘at’ or ‘below’ expected levels of ‘moving and handling’ skills, as part of a wider assessment of childhood development called the Early Years Foundation Stage Profile (EYFSP). In 2019, 89.2% of children in England were found to be ‘at’ or ‘exceeding’ expected levels for moving and handling (Department for Education, 2019a). However the guidelines for assessment are rather vague and somewhat subjective, with teachers being asked whether children (i) show good control and co-ordination in large and small movements, (ii) move confidently in a range of ways, safely negotiating space and (iii) handle equipment and tools effectively, including pencils for writing (Department for Education, 2020). Greater focus on motor skills is evident in Key Stage One (KS1; i.e. children aged 5-7) where the development of FMS are a key outcome within Physical Education (Department For Education, 2013). The curriculum for this age group states that in KS1, children should be able to master basic skills including running, jumping, throwing, catching and balance (Department For Education, 2013). Despite this focus in the curriculum though, these expectations are never formally assessed in KS1. Introducing assessments of FMS into Physical Education (P.E.), where these skills are already being practiced, should therefore not be considered an additional burden on schools, rather this would be essential for properly assessing stated learning outcomes within the current curriculum.

Assessing FMS in schools could also help with other initiatives. In particular, there has been increasing pressure on schools to contribute to helping to increase the levels of childhood physical activity (Department for Digital Culture Media & Sport, 2015). It is recommended that children should get a minimum of 30 minutes of moderate-to- vigorous physical activity (MVPA) in school each weekday (Department for Education et al., 2019), which is half of the guideline recommendations (1 hour per day). In order to help schools achieve this goal, the Government has given an additional 32 million pounds worth of funding (the PE and Sport Premium) to improve P.E. and physical activity provision in schools (Department For Education, 2019b). As research has shown that FMS play a crucial role in facilitating participation in physical activity, ensuring children have adequate FMS proficiency will be essential.

Such initiatives may play an even more important role in response to delays in childhood development attributed to the COVID-19 pandemic. Surveys of parents have found that a large proportion of children (72%) did less physical activity during lockdown (Pombo et al., 2020) and used play facilities less (Guan et al., 2020). A large longitudinal cohort study found that over a third of children failed to leave the house during lockdown, and that only 29% of children were meeting physical activity guidelines, with a disproportionately low amount of children from a South Asian heritage being included within this statistic (Bingham et al., 2021). Additionally, initial reports from the Office for Standards in Education, Children's Services and Skills suggests that on their return to school, the physical skills of pupils had regressed (Ofsted, 2020).

The concept of assessing FMS within school time is not a new one, in both Canada and Australia this is trialled and implemented in different ways. In Canada, Partnering for Change incorporated OTs into school settings to help support children with additional needs (Missiuna et al., 2017). Results from this study were promising, as children were highlighted as struggling with motor skills much earlier than using the traditional model of assessment; children identified by the school OT were identified on average one year earlier than those on the waiting list (Missiuna et al., 2017). Additionally, there was also less gender bias, whereby there was an increase in the number of girls being identified. There were only 11 girls on the waiting list for assessment, but through classroom observation the OTs identified 27 additional girls who were then referred for assessment (Missiuna et al., 2017). Although not all children were screened for movement difficulties using this collaborative approach between healthcare and education services, OTs did observe lessons and assess children that were not participating as much, as well as children who were on the waiting list for assessments. In Australia the approach was slightly different. Schools within the state of Victoria, and Western Victoria were given a manual on FMS that also instructed teachers on how to assess them within P.E. lessons (Department of Education Victoria, 2009; Department of Education Western Australia, 2013).

1.5.2.2 Assessment Tools Available

There are a wide range of assessment tools that could be used to measure FMS in schools (see Figure 5). These involve both subjective and objective methodologies (Bardid, Vannozzi, et al., 2019). Within subjective methods there are self-report (child) and proxy report (teachers) which utilise questionnaires to establish perceived abilities. These methodologies are relatively low cost, and quick to implement, meaning that a large number of children can be assessed (Bardid, Vannozzi, et al., 2019). The speed at which these questionnaires could be implemented in schools would be beneficial to enable universal screening. There are, however, severe limitations to such approaches. A recent meta-analysis found that although research generally shows a relationship between a child's actual and perceived motor competence, the effect size of this relationship is small (De Meester et al., 2020). Some research even suggests there are no correlations between these variables (Estevan et al., 2018; Liong et al., 2015). With evidence suggesting that children are poor at estimating their own FMS ability, particularly in younger age groups (Ali Brian et al., 2018; Liong et al., 2015; True et al., 2017), it is difficult to justify the use of self-report in universal screening programmes in schools. There has been limited research on how accurate teachers' proxy reports are with regards to childhood FMS ability. The research that has been done in this area has found mixed results with some studies suggesting that teacher reports are more accurate than child self-report (Estevan et al., 2017) and other suggesting the contrary (Lalor et al., 2016). One particular issue with teacher proxy reports is that they do not require the teachers to watch pupils performing the skills, and it is therefore possible that memory and judgement may bias the accuracy of these assessments (Bardid, Vannozzi, et al., 2019). Due to the subjectivity of proxy reports, it is again questionable whether it would be a valid methodology for use in screening, particularly as there is a lack of P.E. specialists within the UK (Ofsted, 2013) that would have a working knowledge of FMS.

In contrast to self-report and proxy report, there are objective assessments available for assessing FMS in children. One subset within this class of methodologies is motion devices, which analyse movement using specialist equipment (e.g. cameras, force plates and motion sensors) to quantify movement. There is a wide range of technologies used to measure FMS in this context, including inertial measurements units (e.g. accelerometers), motion sensors, and force platforms (Clark et al., 2021). These methods are relatively new in comparison to other measures, and are advancing alongside technological improvements to offer a completely objective overview of children's motor ability. In recent years, these motion devices have become wearable outside of a lab setting (e.g. gyroscopes and accelerometers), and thus research is being done on the best placement for these devices and how to classify FMS using this technology (Duncan, Dobell, et al., 2020; Duncan et al., 2019). Research has shown that these devices can differentiate between different FMS ability levels in children (Grimpampi et al., 2016), but that certain skill criteria can be misclassified (Lander et al., 2020). A recent systematic review has highlighted the need for more large scale studies evaluating the validity, reliability and usability of these methods (Clark et al., 2021). Although sensor technology has promise, and will likely improve in the coming years, they have a number of limitations that undermine their utility in a school setting currently. Firstly, motion devices are costly (Bardid, Vannozzi, et al., 2019) and, with the pressure on school budgets predicted to worsen (Perera, 2020), it is unlikely that schools would be able to invest such technology. Additionally, they require specialist knowledge of how to process the data and extract meaningful results (Bardid, Vannozzi, et al., 2019), which most schools are unlikely to have. Thus, without extensive training, the data collected would be meaningless for schools.

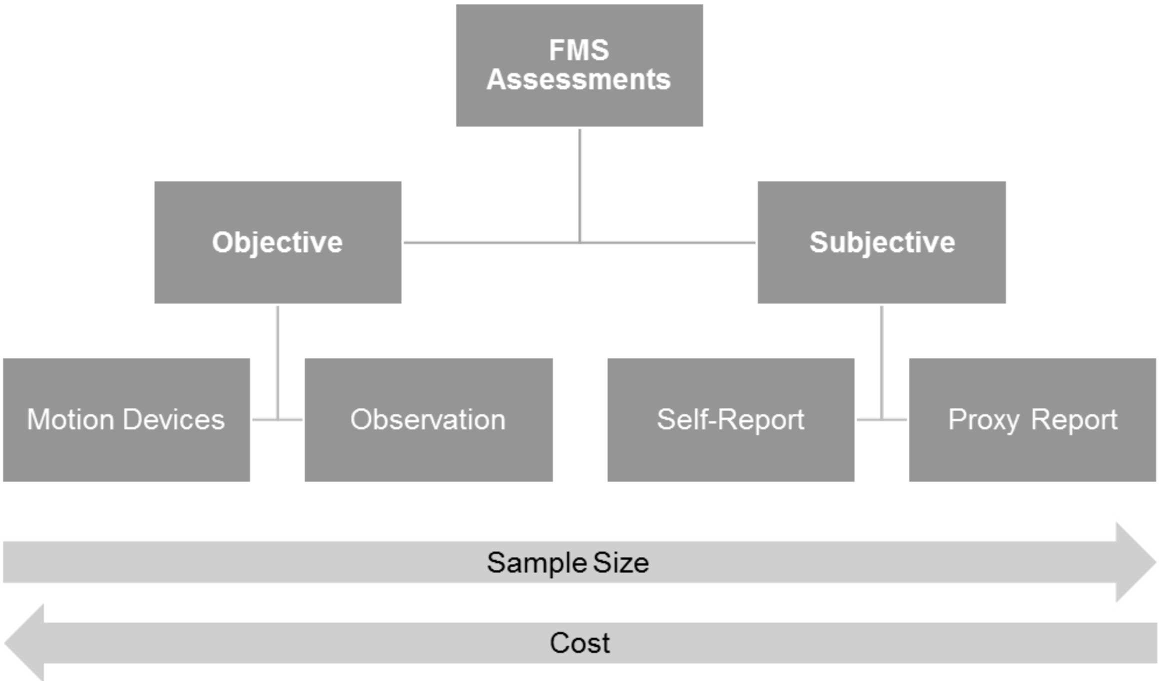


Figure 5 – Methods of assessment available to measure FMS in school-aged children

NB: Figure modified from Bardid et al. (2019).

The assessment tools that have been utilised in the school-testing initiatives in Canada and Australia, outlined in section 1.4.2.1, were observational. Observational assessment tools require an assessor to watch a child physically performing a skill and score them based on a set of pre-determined criteria. In the Canadian model, OTs used the Movement Assessment Battery for Children

(Hendersen et al., 2007), a well-known diagnostic tool used within clinical settings to evaluate motor proficiency. In Australia, a purpose-made assessment was designed for teachers to implement (Department of Education Victoria, 2009; Department of Education Western Australia, 2013).

Observational assessment tools offer a middle ground to schools, in that they are less expensive than motion devices, but also less subjective than self- or proxy-reports. They also can be designed to require minimal data entry. It could therefore be argued, that out of the four possible methodological approaches available to assess childhood FMS proficiency, observational assessments are the most feasible for use in schools, particularly because these measures have been implemented successfully in school-based initiatives previously overseas (Department of Education Victoria, 2009; Department of Education Western Australia, 2013; Missiuna et al., 2017). However, even when focusing on observational assessment tools alone, there are a large number of different assessment tools which could be used to measure the FMS of school-aged children (Klingberg et al., 2018), with new tools being developed all the time. In addition to this, the psychometric properties of these assessment tools are also not always readily available, which makes evaluating their utility for school-based screening difficult.

1.6 Thesis Aims

This thesis therefore aims to:

(i) Understand what observational assessment tools are currently available to measure FMS in school-aged children, which could be used for universal screening, and evaluate the validity and reliability of these assessment tools

(ii) Examine what factors would make FMS assessments feasible for use in a school setting

(iii) Develop a teacher-led assessment tool that has strong theoretical and psychometric underpinnings, that is also suitable for use in a universal screening programme of FMS ability in Primary schools

(iv) Evaluate the validity, reliability, feasibility and acceptability of the new assessment tool

1.7 Thesis structure

The studies undertaken for this thesis addressed these aims as follows.

Chapter Two - This chapter includes a comprehensive systematic review that synthesises peer-reviewed literature on the psychometric properties of the assessment tools that currently exist for the evaluation of the FMS of school-aged children.

Chapter Three – This chapter reports the findings from of an online questionnaire, which was designed using behaviour change theories (Capability, Opportunity, Motivation, Behaviour model (Michie et al., 2011) and the Theoretical Domains Framework (Cane et al., 2012) to understand, from the viewpoint of teaching staff, what barriers and facilitators there are to implementing school-based assessments of FMS. By utilising behaviour change frameworks, guidelines were able to be formulated which detailed both (i) what school-based FMS assessments should entail, and (ii) accompanying behaviour change techniques that should be implemented to increase the likelihood of school-based assessments of FMS becoming a reality.

Chapter Four – This chapter details three studies that were used to help guide the development of a new teacher-led assessment of FMS (FUNMOVES), based on the guidelines set out in chapter 3. These three studies iteratively evaluate the structural validity of FUNMOVES using Rasch analysis, and detail modifications made based on Rasch and implementation fidelity results from each study.

Chapter Five - comprises a protocol with two work packages. The first work package proposes exploring additional aspects of validity and reliability, as per the COSMIN checklist. The second work package proposes using focus groups with teachers that have implemented FUNMOVES to evaluate feasibility and acceptability. Unfortunately, due to COVID-19, this protocol was not able to be actioned within the timeframe of this PhD.

Chapter Six – This final chapter includes an overview of the findings and implications from the previous five chapters, and outlines directions for future research.

For an overview of how the chapters link see Figure 6.

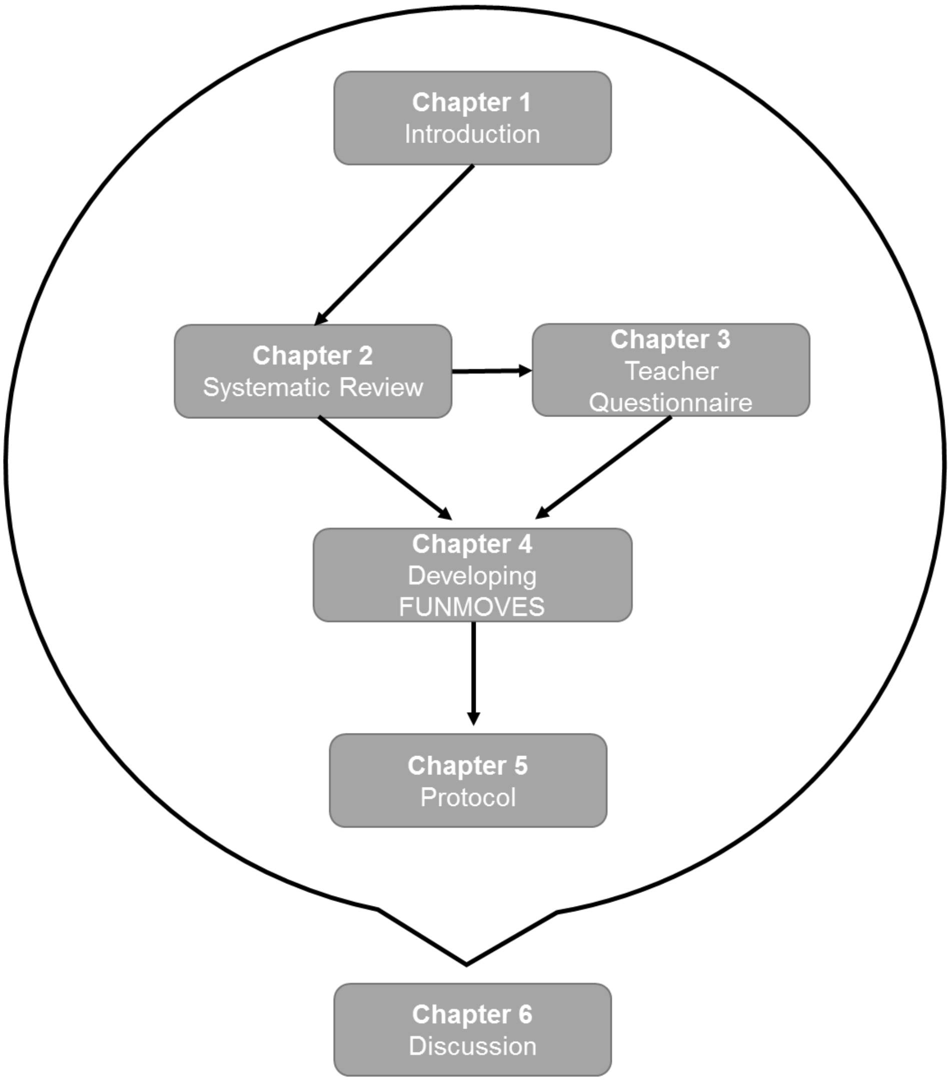


Figure 6 – Diagrammatic representation of the thesis structure

1.8 My Role

For the duration of the PhD, I was based in the School of Psychology at the University of Leeds and the Bradford Institute for Health Research (BIHR), which hosts the Born in Bradford (BiB) birth cohort study. BIHR and BiB acted as an industrial partner in my funding. BiB is a longitudinal cohort study which begun in 2007 that is tracking the health and wellbeing of over 13,500 children and their families. Beyond this, BiB also uses their contacts and expertise to facilitate and conduct research (such as that included within this thesis) within Bradford schools. This research often contains a mix of BiB children and children not involved in the cohort. I have also been involved with Centre for Applied Education Research (CAER) since it opened in 2019. CAER aims to empower schools to ensure that children have the best possible start in life, and education. It was created by the Bradford Opportunity Area (BOA), this was one of twelve Opportunity Areas that the Department for Education funded to work in areas identified as 'social mobility cold spots'. Consequently, the BOA has since received prioritisation of resources to improve outcomes for children in the area.

For the studies in Chapters 2-5 (protocol included) I wrote the ethics application. For the systematic review in Chapter two I (alongside my supervision team) planned the scope of the review, and I subsequently wrote the protocol for the methods so that they could be pre-registered on PROSPERO. I reviewed all articles during both title and abstract screening. I also trained and supervised a team of BiB interns to help with screening, data extraction and risk of bias assessment. I wrote up the review for both publication and for inclusion in this thesis.

For Chapter Three I, alongside my supervision team, designed the online questionnaire for teachers. I advertised the questionnaire on social media (Twitter, and teacher groups on Facebook) and on Bradford Schools Online. I held discussions with my supervision team about the alignment of this research to the COM-B and TDF models of behaviour change. I processed and cleaned the data, and completed all data analysis for this chapter. I also wrote up the results of the questionnaire for both publication and for inclusion in this thesis.

I led the initial development of FUNMOVES and all three studies in Chapter Four. I presented the 'regularly included' activities for pre-existing FMS assessments (based on the results from Chapter 2) to the working group, and we discussed which to include, and how each activity should work based on feasibility criteria outlined in Chapter 3. I was responsible for creating all of the resources for testing (e.g. consent forms, teacher manuals, score sheets, implementation fidelity checklists), and training the teachers prior to testing. I was also present for testing in all schools, to evaluate implementation fidelity and assist with any queries the teachers had. After testing I inputted, and cleaned the data from all schools, and then conducted the Rasch analysis for all studies (in conjunction with Nick Preston for Study 1). After each round of testing I also hosted meetings with the working group to discuss the iterative changes to FUNMOVES. I also wrote up these three studies for both publication and for inclusion in this thesis.

For Chapter Five I designed the protocol, with support from my supervision team. I edited the ethics application at the start of the COVID-19 pandemic to reflect more 'COVID safe practices' in the hope that testing may be able to take place before the end of my PhD. I coordinated with interested schools about testing, and the protocol was almost enacted on a number of occasions but due to circumstances within schools, and indeed university policies on data collection during the pandemic, unfortunately this research was never conducted. I am, however, in discussions with schools presently and I am preparing to undertake this work in the near future.

Chapter 2
Systematic Review of Observational Assessment Tools Available to Measure the Fundamental Movement Skills of School-Aged Children

2.1 Background

Chapter 1 established the need for universal screening of children's FMS and outlined the important role observational assessment tools could play in such a task. It was noted that there were a large number of observational assessment tools that could be suitable for this purpose. However, it is unclear which of these options represent the best choice for schools. For example, which are the most valid and reliable assessments currently available? Thus, there is a need for a systematic review in this area.

The measurement of FMS will play a particularly crucial role in schools, due to the unique nature of these settings. Measurement is particularly difficult as it requires there to be a relationship between theoretical constructs (e.g. FMS) and observable behaviours, such as how fast a child can run (Carmines & Zeller, 1979). When this relationship is strong, it enables useful inferences to be made about the underlying theoretical constructs (Carmines & Zeller, 1979) however, errors in measurement can have a detrimental effect on the conclusions that can be made in research. There are two different types of error that can occur in measurement; systematic and random. Systematic errors occur when the assessment tool that you are using is wrong by consistently the same amount every time that you use it (Drost, 2011). One example of this would be if you were trying to measure how far a child can throw but the tape measure does not have accurate measurements on it, with the distance between each centimetre marking actually 1.5 centimetres in distance. This would mean that the score given to every child would be reflective of two thirds of the actual distance they had thrown. Random errors are caused by factors which vary between measurements (Drost, 2011). One example of this would be if children were being tested in the playground on how well they can hop, and the surface was uneven in some places, this may have an impact upon a child's balance and thus, score. These differences are not, however, consistent, as where the child hops will depend on where in the playground they were assessed. As there are many things that can cause variability in outcome, it is important to evaluate, not only the errors in measurement (reliability) but also those in the assessment tool used (validity) (Drost, 2011).

It is particularly important for any assessment tool that is selected for use in universal screening programmes in schools to be valid and reliable, for a number of reasons. Firstly, it is imperative that the tool for measuring FMS, does so in a manner consistent with how FMS is defined in the Primary school P.E. curriculum, in order for it to have relevance for educators. The syllabus includes the practice of locomotor, object control and stability skills (Department For Education, 2013). Without all these skills being measured, it is likely that it will limit the clinical inferences that can be made (Haynes et al., 1995), and as such, it would be difficult to identify children struggling with the development of the skills that the Department for Education classify as important to a child's development in schools. As teachers already feel under severe time pressure to deliver the 'core' curriculum (i.e. English, Mathematics and Science) (Routen et al., 2018), it is also crucial that any additional assessment introduced within the school day can efficiently distinguish between ability levels and provide useful information about pupils' development. In addition to this, with screening likely to take place infrequently, such as annually, it is important that the scores children receive are representative of their actual ability, and are not caused by measurement factors such as who implemented the assessment, or because the scoring of activities are not stable over time. Where such sources of error present, children may be misidentified as having problems with FMS, and the limited resources schools have may be unintentionally misplaced for the year.

In this chapter, a systematic review was undertaken to:

(i) establish a comprehensive summary of the observational tools currently used to measure FMS that have been subjected to scientific peer-review.

(ii) examine and report the validity and reliability of such assessments, to provide an overview of assessment tools which may be suitable for universally screening FMS in schools.

2.2 Methods

Methods for this systematic review were registered on PROSPERO (CRD42019121029), a copy of which can be found in Appendix A.

2.2.1 Inclusion Criteria and Preliminary Systematic Search

A preliminary search was conducted to identify assessment tools that were identified in peer-review published research as measures of FMS in school-aged children. This pre-search was conducted in seven electronic databases

(PubMed, Medline, Embase, CINAHL, SportDiscus, PsycInfo and Web of Science) in December 2018, and was subsequently updated in May 2020. It used the search terms ‘fundamental movement skills’ OR ‘fundamental motor skills’. Assessment tools identified in this pre-search were included in the subsequent review if they were confirmed to: (i) assess fundamental movement skills, including locomotor, object control and/or stability skills (Gallahue et al., 2012) (ii) observationally measure actual FMS competence (i.e. physical, observable abilities); (iii) assess children on a standard battery of tasks which were completed in the presence of an assessor. Proxy reports and assessments that measured perceived motor competence were therefore excluded from the review. No restrictions were placed on the health or development of included participants, as befits investigations within a school context because any assessment tool that is going to be used in an educational setting would need to be appropriate for use with children of a variety of ages, both with and without developmental difficulties.

The titles and abstracts of the results of this pre-search were screened by the lead reviewer (Lucy H. Eddy [LHE]) to identify assessment tools mentioned within them that were being used to assess FMS. Any studies stating they were assessing FMS but omitting mention of the specific assessment tool in the title or abstract underwent a further full text review.

2.2.2 Electronic Search Strategy and Information Sources

The search strategy developed (see Appendix B) was applied in seven electronic databases (PubMed, Medline, Embase, CINAHL, SportDiscus, PsycInfo and Web of Science) in January 2019, and was then updated in May 2020. Conference abstracts that were identified were followed up by searching for the full articles or contacting authors to clarify whether the work had been published.

2.2.3 Study Selection

For the initial search (Dec 2018), titles and abstracts were screened in their entirety by one lead-reviewer (LHE), and two co-reviewers (Nishaat F. Shahid & Kirsty L. Crossley [researchers]) independently assessed half each. The same process was followed for full text screening to identify eligible studies. Reviewers were not blind to author or journal information and disagreement between reviewers was resolved through consultation with a fourth reviewer (Daniel D. Bingham [supervisor]). For the update (May 2020), the same process was repeated but with two different co-reviewers (Marsha Ellingham-Khan & Natalie S. Figuero).

2.2.4 Data Extraction Process & Quality Assessment

Three reviewers each extracted information from a third of the studies in the review in both the initial search (LHE, KLC & NFS) and the update (ME-K, NSF & Ava Otteslev). Data extraction and an assessment of the methodological quality of each study were completed using the Consensus-based Standards for the Selection of health Measurement INstruments (COSMIN) checklist (Mokkink et al., 2010b), which outlines guidance for the reporting of the psychometric properties of health-related assessment tools. Information was extracted on: (i) author details and publication date; (ii) sample size and demographic information related to the sample; (iii) the assessment tool(s) used; (iv) the type(s) of psychometric properties measured by each study; (v) the statistical analyses used to quantify validity or reliability, including whether they were measured using classical test theory (CTT) or item-response theory (IRT); and (vi) the statistical findings. Methodological quality ratings for each study were recorded as the percentage of the standards that it had met for its included psychometric properties and generalisability. When an IRT method was used, a second quality percentage was calculated, based on the COSMIN guidelines for IRT models (Mokkink et al., 2010b). The lead reviewer (LHE) and a second reviewer (AO) each evaluated half of the studies for methodological quality, with a 10% cross-over to ensure agreement. Agreement was 100%, so no arbitration was necessary.

2.2.5 Interpretation of Validity and Reliability

Many studies used different terminologies to describe the same type of validity or reliability, so it was necessary to set a definition for each psychometric property and categorise study outcomes in accordance to the COnsensus-based Standards for the selection of health status Measurement Instruments (COSMIN) checklist (Mokkink et al., 2010b) (see Table 1). Interpretability and face validity (sub-categories of content validity) were not included as these could not be quantified using statistical techniques. Responsiveness was not included because this is recognised as being separate to validity or reliability within the COSMIN guidance.

Table 1 – Definitions of Validity and Reliability defined by the COnsensus-based Standards for the selection of health status Measurement Instruments

COSMIN category	Psychometric Property (if different from COSMIN category)	Definition
Reliability	Inter-Rater Reliability	The level of agreement between different assessors' scores of children on an assessment tool.
	Intra-Rater Reliability	How consistent an assessor is at scoring children using an assessment tool.
	Test-retest Reliability	The stability of the children's scores on an assessment tool over a minimum of two time points.
	Internal consistency	The level of agreement between items within an assessment tool.
Content Validity		The extent to which an assessment is representative of the components/facets it was designed to measure.
Construct Validity	Structural Validity	The degree to which an assessment tool measures what it was designed to measure.
	Cross-Cultural Validity	The degree to which an assessment tool and its' normative data can be used to assess FMS in countries other than the one it was designed in.
	Hypotheses Testing	The degree to which scores on assessments are consistent with hypotheses made by authors (e.g. internal relationships between subscales, relationships to scores of other assessment tools or differences between relevant groups.

COSMIN category	Psychometric Property (if different from COSMIN category)	Definition
Criterion Validity	Concurrent Validity	The level of agreement between two assessment tools.
	Predictive Validity	The degree to which performance on an assessment tool can be used to predict performance on another measure, tested at a later date.

Due to a large variation in the statistical tests used to assess validity and reliability, a meta-analysis was not feasible. To enable easier interpretation of the findings studies that utilised different statistical analyses, a traffic light system was instead used (poor, moderate, good and excellent; see Table 2).

Table 2 - Traffic light system for analysing results of included studies

	Level of Evidence			
Statistical Method	**Poor**	**Moderate**	**Good**	**Excellent**
Intraclass Correlation (ICC) (Koo & Li, 2016)	<.5	.5 - .75	.75 - .9	>.9
Pearson Correlation (Chan, 2003)	<.3	.3 - .6	.6 - .8	>.8
Spearman Correlation (Chan, 2003)	<.3	.3 - .6	.6 - .8	>.8
Kappa (McHugh, 2012)	<.6	.6 - .79	.8 - .9	>.9
Cronbach's alpha (Streiner, 2003)	<.6	.6 - .7	.7 - .9	>.9

NB: For Kappa statistics, the first three thresholds described by the authors ("none", "minimal" and "weak" were combined to form "poor" in the table above (McHugh, 2012). For Cronbach's alpha, "unacceptable" and "poor" were combined to be classified as "poor" for the purpose of this review (Streiner, 2003).

This allowed certain results to be grouped into different bands, according to thresholds for these statistical values suggested in previous research. The results of all analyses which utilised other forms of statistical analysis (i.e. tests not listed in Table 2) are described in the text. For the studies that included multiple metrics for each psychometric property, the traffic light colour used to represent these multiple measures reflects the mean value of the specific FMS related task scores, or subtest scores, as appropriate. A full breakdown of results for each study can be found in Appendix C.

2.3 Results

2.3.1 Assessment Tools

The pre-search identified 33 possible FMS assessment tools of which three were removed for not meeting criteria 1 (measuring fundamental movement skills). These were Functional Movement Screen (Cook et al., 2006a, 2006b), Lifelong Physical Activity Skills Battery (Hulteen, Barnett, et al., 2018), New South Wales Schools Physical Activity and Nutrition Survey (Booth et al., 2006). Two were removed for failing criteria 3 (assessing children on a standard battery of tasks, completed in the presence of an assessor). These were Fundamental Motor Skill Stage Characteristics/ Component Developmental Sequences (Haubenstricker & Seefeldt, 1986) and the Early Years Movement Skills Checklist (Chambers & Sugden, 2002). Additionally three tools were identified as being the same assessment tool, with the name translated differently- the FMS assessment tool, the Instrument for the Evaluation of Fundamental Movement Patterns and the Test for Fundamental Movement Skills in Adults (Jiménez-Díaz et al., 2013). The APM-Inventory (Numminen, 1995) and the Passport for Life (Physical Health Education Canada, 2014) were also excluded as no information could be found explaining these assessment tools, and authors either did not respond to queries or no contact information could be found for the author. This left 24 assessment tools for inclusion in the systematic review, which reviewed studies if they: (i) used assessment tool(s) identified in the pre-search; (ii) measured validity or reliability quantitatively; (iii) sampled children old enough to be in compulsory education within their country. Studies were not excluded based on sample health or motor competence. Concurrent validity was only examined between the 24 assessment tools identified in the pre-search.

2.3.2 Included Studies

Electronic searches initially identified 3749 articles for review. Figure 7 demonstrates the review process which resulted in 90 studies being selected (for study table see Appendix C).

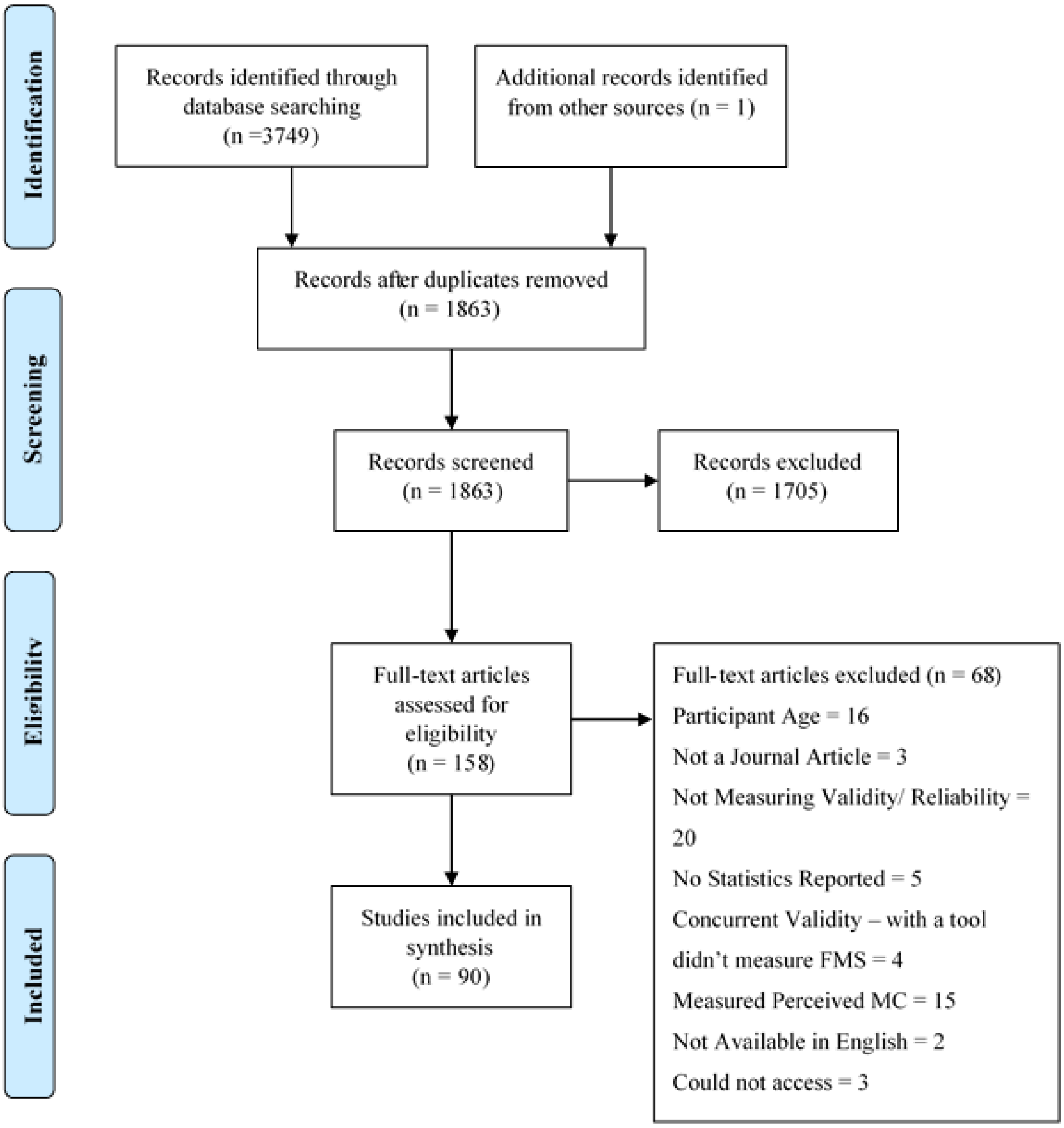


Figure 7 – PRISMA flow diagram illustrating the review process

Included articles explored the validity and/or reliability of sixteen of the assessment tools identified in the pre-search. The search did not identify any articles for the remaining eight assessment tools (see Table 3), so the reliability and validity of these measures could not be evaluated in this review.

Only nine of the assessment tools identified in the pre-search assess all three components of FMS: locomotion, object control and balance (Gallahue et al., 2012). These are: the Bruininks-Oseretsky Test of Motor Proficiency (BOT) (Bruininks, 1978; Bruininks & Bruininks, 2005), FMS Polygon (Žuvela et al., 2011), Get Skilled Get Active (GSGA) (NSW Department of Education and Training, 2000), Peabody Developmental Motor Scale (PDMS) (Folio & Fewell, 1983, 2000), PLAYfun (Stearns et al., 2019), PLAYbasic (Canadian Sport for Life, 2013), Preschooler Gross Motor Quality Scale (PGMQ) (Sun et al., 2010), Stay in Step Screening Test (Department of Education Western Australia, 2013), and the Teen Risk Screen (Africa & Kidd, 2013). Of these assessments, three were product and five were process-oriented. Figure 8 shows a breakdown of the number of assessment tools which measure each aspect of FMS. All assessment tools measured some form of locomotor ability, however there was a large number of different skills assessed within this subscale (*n*=13). The most commonly measured locomotor skills were jumping (*n*=24), hopping (*n*=23) and running (*n*=20). Object control skills were measured by twenty three assessment tools, with the most popular outcomes being catching (*n*=21), throwing (*n*=19) and kicking (*n*=15). Stability skills were only assessed by ten assessment tools, of which eight measured some form of static balance, five measured walking heel to toe and two measured a child's ability to walk along a beam. Other aspects of motor development were also measured by some of the included assessment tools (e.g. the Movement Assessment Battery for Children [MABC] includes a subscale measuring manual dexterity subscale). However this review specifically focused on reporting on measures of FMS within these broader assessment batteries.

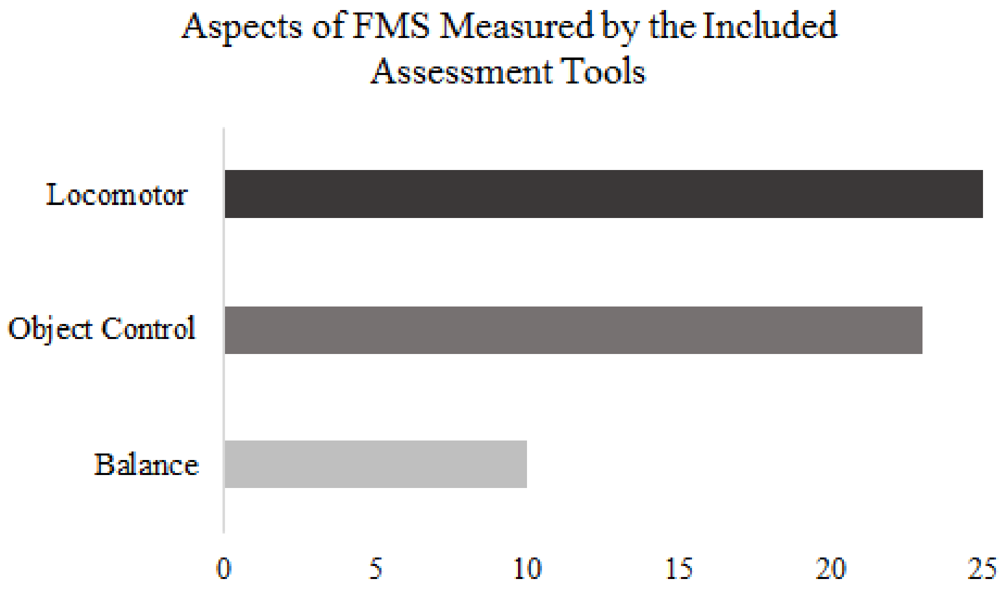


Figure 8 - Graphical representation of the number of assessment tools which evaluate each of the three aspects of FMS.

2.3.3 Participants

The included studies recruited a total of 51,408 participants aged between three and seventeen years of age, with sample sizes that ranged from 9 to 5210 (mean= 556 [SD = 1000] median = 153 [IQR =652]). Twenty-four studies included additional sample demographics, with seven studies recruiting children with movement difficulties (Smits-Engelsman et al., 2008; Tan et al., 2001), Cerebral Palsy (Iatridou & Dionyssiotis, 2013; Liao et al., 2001) or

Developmental Coordination Disorder (Valentini et al., 2015; Wilson et al., 2000; Wuang et al., 2012). Two studies included participants with Autistic Spectrum Disorder (Allen et al., 2017; Borremans et al., 2009), and another study recruited children from special educational needs (SEN) schools (Van Waelvelde et al., 2004). Eight studies defined themselves as sampling children with learning and/or attentional problems (Capio et al., 2016; Crawford et al., 2001; Kim et al., 2012; Mancini et al., 2020; Simons et al., 2008; Wilson et al., 2000; Wuang et al., 2009; Wuang & Su, 2009). Three studies recruited children with visual impairments (Bakke et al., 2017; A Brian et al., 2018; Houwen et al., 2010) and the sample of one study included children with a disability or chronic health condition (Field et al., 2020). Information regarding socioeconomic status (SES) was included in one article which stated they sampled from a low SES population (Ré et al., 2018). Meanwhile, two studies recruited samples from indigenous populations, in Australia and Canada, respectively (Lucas et al., 2013; Stearns et al., 2019), the former of which focused on the recruitment of children whose mothers drank alcohol during pregnancy (Lucas et al., 2013). Studies evaluating the validity and reliability of FMS assessment tools were conducted in 29 countries, with Australia hosting the most studies (13), followed by Brazil (12 studies) and the USA (nine studies). Eight studies were carried out in Belgium and seven in Canada. The remaining 23 countries spanned Europe (23 studies from 15 countries), Asia (10 studies from 7 countries), South America (one study from Chile) and Africa (one study conducted in South Africa). Two studies did not provide any information regarding where the sample was recruited from (Capio et al., 2011; Darsaklis et al., 2013).

2.3.4 COSMIN Quality Assessment

Figure 9 shows the results of the generalisability subscale of the quality assessment for the included studies. The COSMIN checklist (Mokkink et al., 2010b) revealed multiple issues with reporting in the included studies, with 85% of studies not providing enough information to make a judgement about missing responses, and 76% of studies failing to report the language with which the assessment tool was conducted. Additionally, over a third of the studies included in this review did not adequately describe the method used to recruit participants, the age of participants, or the setting in which testing was conducted.

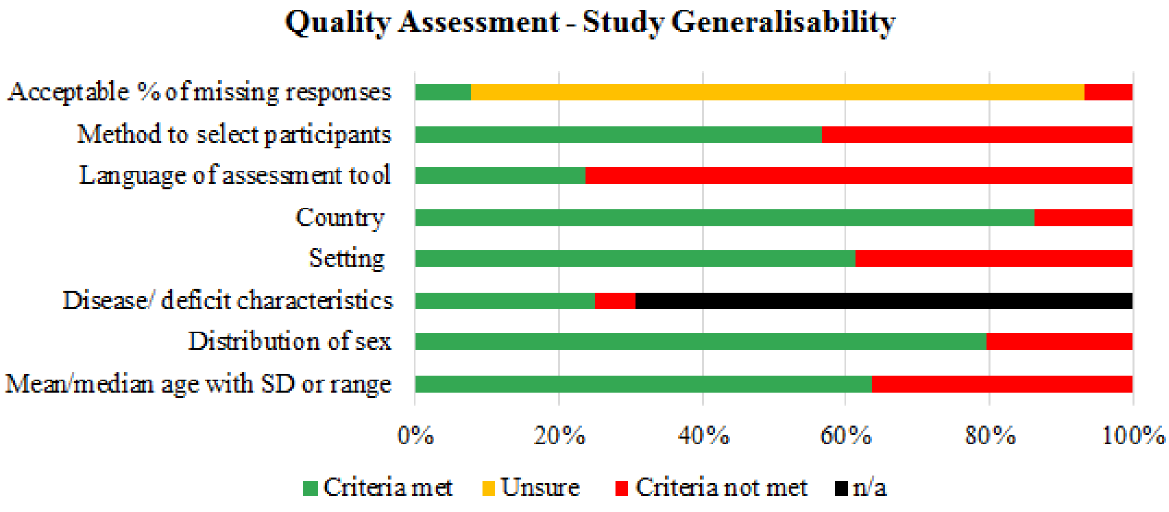


Figure 9 - Summary of the generalisability subscale of the COSMIN checklist

2.3.5 Assessment Tool Categorisation

The observational assessment methods reviewed were defined categorically as either assessing FMS using a "process" or "product-oriented" methodology (Logan et al., 2017). Product-oriented assessments measure the outcome of a movement, for example, how far a child can run in ten seconds. Process-oriented assessments on the other hand evaluate how a movement is completed. For example, whether a child's knees achieve a ninety degree angle to the floor when they are running. Given these two different approaches to measuring FMS, which can be used for different purposes in the literature, they were distinguished between in this review. Of the 24 assessment tools identified (summarised in Table 3) Eight were product-oriented, fourteen were process-oriented, and two assessment tools included both process and product elements within their methodologies.

2.3.6 Product-Oriented Assessments

Despite the pre-search identifying eight product-oriented assessments in the FMS literature, the systematic review only identified research on the validity and reliability of six of these measures (described below). No evaluations of the psychometric properties of any of the following assessments were found: the FMS Test Package (Adam et al., 1988; Kalaja et al., 2012) and the Stay in Step Screening Test (Department of Education Western Australia, 2013).

2.3.6.1 Movement Assessment Battery for Children (MABC)

Twenty-three studies evaluated the validity and/or reliability of the MABC or MABC-2. All of the ten COSMIN categories this review focused on (see Table 1) were evaluated for the MABC. Overall there was strong evidence for inter-rater reliability for these assessments (see Table 4). However, there were more mixed results for other aspects of validity and reliability, with the weakest evidence being found in support of its internal consistency. Intra-rater reliability was only looked at in two studies (Holm et al., 2013; Valentini et al., 2014), with poor intra-rater reliability (ICC =.49) for both the balance and aiming and catching subtest) demonstrated in the study exploring this construct in Norwegian children (Holm et al., 2013). There was good evidence for test-retest reliability, with just one out of five studies, involving a sample of teenagers (Chow et al., 2002), finding only moderate correlations (mean ICC for FMS skills = .74). An adapted version of the MABC-2 was also tested (e.g. increasing the colour contrast on the ball), with results showing that the modified version was a reliable assessment tool for use with children with low vision (inter-rater reliability – ICC = .97; test-retest reliability– ICC = .96; internal consistency- Cronbach's alpha ranged from 0.790 to 0.868) (Bakke et al., 2017).

Strong evidence for content validity was found for both the Brazilian (Valentini et al., 2014) and the Chinese (Hua et al., 2013) versions of the assessment tool, with concordance rates amongst experts ranging from 71.8%-99.2%. Additionally, one study found that children with Asperger syndrome perform worse on all three subtests of the MABC than typically developing children, as hypothesised (Borremans et al., 2009).

Table 3 - The psychometric properties measured for each assessment tool found to measure FMS proficiency

Assessment Tool	**FMS Measured (subscales)**	**Outcome(s)**	**Number of Validity /Reliability Studies**	**Types of Validity and Reliability Assessed**
Athletics Skills Track (AST) [a] (Hoeboer et al., 2016)	AST-1: Crawl, hop, jump, throw, catch, kick, running backwards AST-2: crawl, walk, jump, roll, hopping	Time taken to complete the course	2	Test-Retest Reliability Internal consistency
Bruininks-Oseretsky Test of Motor Proficiency (BOT) [a] (Bruininks, 1978; Bruininks & Bruininks, 2005)	Balance: static balances (e.g. standing on one leg) and dynamic balance (e.g. walking along a line) Running speed and agility: running, hopping, jumping	Time taken to complete tasks, number of tasks completed in a set time limit	22	Inter-Rater Reliability Test-Retest Reliability Internal Consistency Structural Validity

Assessment Tool	FMS Measured (<u>subscales</u>)	Outcome(s)	Number of Validity /Reliability Studies	Types of Validity and Reliability Assessed
	<u>Upper limb coordination:</u> catching, dribbling, throwing			Concurrent Validity Cross-Cultural Validity Hypothesis testing validity
Canadian Agility and Movement Skill Assessment (CAMSA) [a,b] (Longmuir et al., 2017)	Jump, slide, catch, skip, hop, kick and run	Time taken to complete the course (converted to points range) and a performance assessment for each skill	3	Inter-Rater Reliability Intra-Rater Reliability Test-Retest Reliability Concurrent Validity
Children's Motor Skills Protocol (CMSP) [b]	<u>Locomotor</u>: run, broad jump, slide, gallop, leap, hop	Number of movement characteristics	0	N/A

Assessment Tool	**FMS Measured (subscales)**	**Outcome(s)**	**Number of Validity /Reliability Studies**	**Types of Validity and Reliability Assessed**
(Williams et al., 2009)	Object control: overarm throw, underhand roll, kick, catch, stationary strike, stationary dribble	observed for each skill		
Fundamental Motor Skills Test Package (EUROFIT, FMS Test Package) [a] (Adam et al., 1988; Kalaja et al., 2012)	Balance, jump and run	Time taken to complete 20m shuttle run, time can stand on one leg, and distance jumped	0	N/A
Fundamental Movement Skill Polygon (FMS Polygon) [a]	Space Covering: Crawling, rolling, running, beam walking,	Time taken to complete tasks	1	Intra-Rater Reliability Structural Validity

Assessment Tool	**FMS Measured (<u>subscales</u>)**	**Outcome(s)**	**Number of Validity /Reliability Studies**	**Types of Validity and Reliability Assessed**
(Žuvela et al., 2011)	Surmounting Obstacles: skipping, hopping, jumping Object Control: Dribble, throw, catch			Concurrent Validity
Furtado-Gallagher Computerized Observational Movement Pattern Assessment System (FG-COMPASS)[b] (Furtado, 2009)	Locomotor: Hopping, jumping, leaping, skipping, sliding Manipulative: Hitting, catching, kicking, dribbling, throwing	Patterns of movement characteristics for each skill	1	Inter-Rater Reliability

Assessment Tool	**FMS Measured (<u>subscales</u>)**	**Outcome(s)**	**Number of Validity /Reliability Studies**	**Types of Validity and Reliability Assessed**
Get Skilled Get Active (GSGA)[b] (NSW Department of Education and Training, 2000)	Static balance, jump, run, catch, hop, leap, gallop, kick, skip, hit, throw, dodge	Ability to consistently complete patterns of movements for each skill in a variety of environments/ contexts	1	Concurrent Validity
Instrument for the Evaluation of Fundamental Movement Patterns [b] (Jiménez-Díaz et al., 2013)	<u>Locomotor:</u> run, jump, gallop, slide, hop <u>Object Control:</u> bounce, catch, kick, strike, throw	Number of points (one per criterion met per skill)	0	N/A

Assessment Tool	FMS Measured (<u>subscales</u>)	Outcome(s)	Number of Validity /Reliability Studies	Types of Validity and Reliability Assessed
Körperkoordinationstest für Kinder (KTK) [a] (Kiphard & Schilling, 2007; Kiphard & Shilling, 1974; Schilling & Kiphard, 2000)	<u>Walking backwards along beams of varying widths</u> <u>Hopping for height</u> <u>Jumping sideways over a slat</u> <u>Moving sideways on boards</u>	Number of steps walked along the beam, number of successful hops/ jumps/ movements	10	Inter-Rater Reliability Structural Validity Concurrent Validity Internal Consistency Hypothesis testing validity
Motoriktest für vier- bis sechsjärige Kinder (MOT 4-6) [a]	<u>Gross Motor:</u> jumping, walking, catching, throwing, hopping	Number of jumps completed, time taken to complete tasks etc. Raw scores are converted into a 3 level ranking scale:	4	Structural Validity Concurrent Validity Hypothesis testing validity

Assessment Tool	**FMS Measured (<u>subscales</u>)**	**Outcome(s)**	**Number of Validity /Reliability Studies**	**Types of Validity and Reliability Assessed**
(Zimmer & Volkamer, 1987)		0 (not mastered) – 2 (mastered)		
Movement Assessment Battery for Children [a] (Hendersen et al., 2007; Henderson et al., 1992)	<u>Aiming and catching</u> Throwing, catching <u>Balance:</u> static balance (e.g. on one leg), dynamic balance (e.g. walking along the line, jumping, hopping)	Number of successful attempts, length of time balances can be held for	37	Inter-Rater Reliability Intra-Rater Reliability Test-Retest Reliability Internal Consistency Predictive Validity Content Validity Structural Validity

Assessment Tool	FMS Measured (<u>subscales</u>)	Outcome(s)	Number of Validity /Reliability Studies	Types of Validity and Reliability Assessed
				Cross-Cultural Validity Concurrent Validity Hypothesis testing validity
Objectives-Based Motor-Skill Assessment Instrument [b] (Ulrich, 1983)	run, gallop, hop, skip, jump, leap, slide, strike, bounce, catch, kick, throw	The number of qualitative motor behaviours exhibited across the FMS measured (/45)	0	N/A
Ohio State University Scale for intra-Gross Motor	<u>Locomotor:</u> walking, running, jumping, hopping, skipping, climbing	Levels of development for each skill 1 (least mature) – 4 (mature	0	N/A

Assessment Tool	**FMS Measured (subscales)**	**Outcome(s)**	**Number of Validity /Reliability Studies**	**Types of Validity and Reliability Assessed**
Assessment (OSU-SIGMA) [b] (Loovis & Ersing, 1979)	Object control: throwing, catching, striking, kicking	functional pattern) based on qualitative assessment of movement patterns		
Peabody Developmental Motor Scale (PDMS)[b] (Folio & Fewell, 1983, 2000)	Stationary Locomotion: crawling, walking, running, hopping, jumping Object manipulation: throwing, catching	Score of 0-2 as to the level of skill shown for each FMS (not demonstrated, emerging, proficient	1	Concurrent Validity
PE Metrics [a,b] (National Association for Sport and Physical	Throwing, catching, dribbling, kicking, striking	Score of 0-4 for form (how well the movement is executed) and success (the	1	Structural Validity

Assessment Tool	FMS Measured (subscales)	Outcome(s)	Number of Validity /Reliability Studies	Types of Validity and Reliability Assessed
Education, 2010, 2011)	Hopping, jumping, galloping, sliding, running, skipping	outcome of the movement)		
PLAYbasic [b] (Canadian Sport for Life, 2013)	Locomotor: run, hop Throw Kick Balance (dynamic- heel to toe backwards)	Levels of development for each FMS – developing (initial or emerging) or acquired (competent or proficient)	1	Inter-Rater Reliability Internal Consistency Concurrent Validity
PLAYfun[b] (Stearns et al., 2019)	Running: run a square, run there and back, run, jump and land on two feet	Levels of development for each FMS –	2	Inter-rater reliability Structural validity

Assessment Tool	**FMS Measured (<u>subscales</u>)**	**Outcome(s)**	**Number of Validity /Reliability Studies**	**Types of Validity and Reliability Assessed**
	<u>Locomotion:</u> skip, gallop, hop, jump <u>Upper body object control:</u> overhand throw, strike, one handed catch, stationary dribble <u>Lower body object control:</u> kick a ball, foot dribble <u>Balance:</u> walk heel-to-toe forwards, walk heel-to-toe backwards,	developing (initial or emerging) or acquired (competent or proficient)		Internal Consistency Concurrent Validity Hypothesis Testing Validity
Preschooler gross motor	<u>Locomotion:</u> Run, jump, hop, slide, gallop, leap	Number of qualitative qualities	0	N/A

Assessment Tool	FMS Measured (subscales)	Outcome(s)	Number of Validity /Reliability Studies	Types of Validity and Reliability Assessed
quality scale (PGMQ)[b] (Sun et al., 2010)	Object manipulation: throw, catch, kick, bounce, strike Static balance: one leg balance, tandem one leg balance, walking along the line forwards, walking along the line backwards	for each FMS each child demonstrates		
Smart Start [b] (Wessel & Zittel, 1995)	Locomotor: run, gallop, hop, leap, jump, slide Object control: strike, bounce, catch, kick, throw	Whether elements of each skill were completed (1= yes, 0 =no)	0	N/A
Teen Risk Screen [b]	Posture & Stability (Axial Movement): sitting, standing,	Extent to which each skill can be performed	1	Internal Consistency Structural Validity

Assessment Tool	**FMS Measured (<u>subscales</u>)**	**Outcome(s)**	**Number of Validity /Reliability Studies**	**Types of Validity and Reliability Assessed**
(Africa & Kidd, 2013)	bending, stretching, twisting, turning, swinging <u>Posture & Stability (Dynamic Movement):</u> body rolling, starting and stopping, dodging and balance <u>Locomotor Skills (Single Skills):</u> walking, running, leaping, jumping and hopping <u>Locomotor Skills (Combinations):</u> galloping, sliding and skipping <u>Manipulative Skills (Sending Away):</u> carrying, dribbling	according to guidelines (0= cannot perform the skill according to guidelines, 1= can perform the skill but not according to the guidelines, 2= can perform the skill)		Test-Retest Reliability

Assessment Tool	FMS Measured (subscales)	Outcome(s)	Number of Validity /Reliability Studies	Types of Validity and Reliability Assessed
	Manipulative Skills (Maintaining Possession): catching			
Test of Gross Motor Development (TGMD)[b] (Ulrich, 1985, 2000, 2016)	Locomotor: run, gallop, jump, hop, skip, leap, slide Object Control: strike, dribble, catch, kick, throw	The number of qualitative motor behaviours exhibited for each of the FMS measured	34	Inter-Rater Reliability Intra-Rater Reliability Test-Retest Reliability Internal Consistency Content Validity Structural Validity

Assessment Tool	FMS Measured (<u>subscales</u>)	Outcome(s)	Number of Validity /Reliability Studies	Types of Validity and Reliability Assessed
				Cross-Cultural Validity Concurrent Validity Hypothesis Testing Validity
Victorian Fundamental Movement Skills Assessment Instrument [b] (Department of Education Victoria, 2009)	Catch, kick, run, jump, throw, bounce, leap, dodge, strike	The number of components of each FMS a child has mastered	1	Concurrent Validity

Assessment Tool	FMS Measured (subscales)	Outcome(s)	Number of Validity /Reliability Studies	Types of Validity and Reliability Assessed
Stay in Step Screening Test [a] (Department of Education Western Australia, 2013)	Static balance (one leg), bounce, catch, hop, run	Duration balance is held for, number of completed throws/catches in a specified timeframe, distance hopped, time taken to complete task (e.g. 50m run)	0	N/A

NB: [a]= product-oriented, [b]= process-oriented

Table 4- Reliability and Validity of the MABC

		Reliability			Validity	
Study		**IeR**	**IaR**	**TR**	**IC**	**Pr**
(Chow et al., 2002)	**MABC**	[green]		[orange]		
(Croce et al., 2001)				[green]		
(Ellinoudis et al., 2008)					[orange]	
(Smits-Engelsman et al., 2008)		[green]				
(Bakke et al., 2017)	**MABC-2**	[green]		[green]	[yellow]	
(Borremans et al., 2009)					[orange]	
(Darsaklis et al., 2013)		[green]				
(Holm et al., 2013)		[orange]	[red]			
(Hua et al., 2013)		[green]		[green]	[red]	
(Jaikaew & Satiansukpong, 2019)		[green]				
(Kita et al., 2016)					[orange]	
(Valentini et al., 2014)		[green]	[yellow]		[yellow]	[yellow]
(Wuang et al., 2012)				[green]	[yellow]	

NB: IeR = interrater IaR = intra rater, TR = test-retest, IC = internal consistency, St=Structural, Ct = content, Pr = predictive. ■= poor (ICC <.5, *r* <.3, *κ*<.6, *α* <.6), ■= moderate (ICC = .5 -.75, *r* = .3 - .6, *κ* = .6 - .79, *α* = .6 - .7), ■= good, (ICC = .75 -.9, *r* = .6 - .8, *κ* = .8 - .9 , *α* = .7 - .9) ■= excellent validity/reliability (ICC >.9, *r* > 8, *κ* >.9 , *α* > .9) .

Cross-cultural validity was studied in four papers, looking at Swedish, Spanish, Italian, Dutch and Japanese samples in comparison to US or UK norms (Niemeijer et al., 2015; Rösblad & Gard, 1998; Ruiz et al., 2003; Zoia et al., 2019). Results showed that UK norms were not suitable for use when evaluating the performance of Italian children, as significant differences were found for eleven of the twenty seven items on the MABC-2 (Zoia et al., 2019). Small differences were also reported between the performance of UK children and Dutch children, however these were not statistically significant (Niemeijer et al., 2015). The US standardised sample was found to be valid for use with a Swedish (Rösblad & Gard, 1998) but not Spanish sample, in the latter case US norms estimated a large proportion of the sample below the 15th percentile (Ruiz et al., 2003).

Structural validity was assessed by ten studies, with six finding evidence for a three factor (manual dexterity, aiming & catching and balance) model (dos Santos et al., 2017; Hua et al., 2013; Kita et al., 2016; Psotta & Abdollahipour, 2017; Wagner et al., 2011; Zoia et al., 2019). One study found a four factor solution, with a general factor for age band 1, four factors with balance split into static and dynamic for age band 2, and a 3 factor correlated model for age band 3 (Schulz et al., 2011). Similarly, another study found evidence for a bi-factor model with one general factor, and three sub-factors for age band one (Okuda et al., 2019). Evidence was also found for a five factor solution, with balance and manual dexterity each split into two factors (Ellinoudis et al., 2008). An adolescent study found a two factor model (manual dexterity and aiming and catching) was more appropriate as ceiling effects were evident on balance tasks (Valtr & Psotta, 2019).

The results of the COSMIN quality assessment of MABC studies show that two studies which found excellent rated results (see Table 4), had the lowest quality ratings, in which they met 13% and 29% of generalisability and inter-rater reliability criteria respectively (Darsaklis et al., 2013; Jaikaew & Satiansukpong, 2019). Additionally, the singular study which found MABC normative data to be valid in another country only had a quality rating of 39% (Rösblad & Gard, 1998). The MABC study with the best quality rating (81% of criteria met), only found moderate results for internal consistency (Kita et al., 2016), and the single study which found that MABC norms data were cross-culturally valid, only had a quality rating of 39%. When considering COSMIN quality ratings alongside the results of these studies, it would suggest that caution should be taken when interpreting their results regarding the psychometric properties of the MABC.

2.3.6.2 Bruininks-Oseretsky Test of Motor Proficiency (BOT)

Twelve studies stated that they explored the validity and reliability of the BOT, BOT-2 or BOT-2 Short Form (SF), of which six reported results that could be quantified into poor, moderate, good and excellent evidence of the various psychometric properties detailed in Table 5. Three studies looked at the inter-rater reliability of the BOT, all of which found at least good evidence in support of this aspect of reliability (Darsaklis et al., 2013; Lucas et al., 2013; Wilson et al., 2000). However, one of these studies provided no information about the sample, including size and demographic information (Darsaklis et al., 2013).

The results for test-retest reliability were more mixed than for the MABC, with two studies finding low correlations on scores between tests sampling from children with Cerebral Palsy (ICC= .4) (Liao et al., 2001) and children living in aboriginal communities in Australia (mean ICC for FMS= .097) (Lucas et al., 2013). One study did show evidence of the BOT being a reliable measure of FMS in children with intellectual deficits (Wuang & Su, 2009). One study explored the cross-cultural validity of the BOT-2 norm scores with a large Brazilian sample (n=931) and found mixed results (Ferreira et al., 2020). Results showed that Brazilian children outperformed the BOT normative data on bilateral coordination, balance, upper-limb coordination, and running speed and agility subtests, but similar percentile curves were found for both populations on upper limb coordination and balance subtests (Ferreira et al., 2020).

Five studies explored the structural validity of the BOT. The BOT-2 SF was also found to have good structural validity once mis-fitting items were removed for children aged 6-8 years, but ceiling effects were found for older children, aged 9-11 years (Bardid, Utesch, et al., 2019). Two studies exploring structural validity utilised Rasch analysis and found good evidence for it. These results were indicative of unidimensionality, with the overarching factor accounting for 99.8% (Wuang et al., 2009) and 82.9% (Brown, 2019b) of the variance in test scores for children with intellectual deficits (BOT), and typically developing children (BOT-BF), respectively. Similarly to the results of the Rasch studies, one additional study found that the four subscales were correlated, with a bi-factor model that had an overarching motor skill factor, and four correlated sub-factors providing the best fit (Okuda et al., 2019). When the subscales and composite scales were evaluated separately using Rasch analysis, one study found multiple issues with the fine motor integration, bilateral coordination, balance and body coordination scales/scores, limiting the justification of their usage as multi-dimensional scales/score. Issues included: Item response working differently for males and females, disordered item difficulty ratings, and/or problems with the ability of the subscale/ composite score to differentiate between abilities (Brown, 2019a).

The quality of the studies evaluating the validity and reliability of the BOT may have influenced the results though, as the study with the greatest quality rating (83%) found only “good” results for inter-rater reliability (Lucas et al., 2013), whilst two studies with lower ratings (13% (Darsaklis et al., 2013) and 53% (Wilson et al., 2000) reported “excellent” results for this psychometric property, suggesting that reliability scores may have been inflated by poorer quality studies. Additionally, the reviewed BOT studies only evaluated seven of the ten COSMIN categories (see Table 1).

Table 5 - Validity and reliability of the BOT

		Reliability				Validity
Study		**IeR**	**IaR**	**TR**	**IC**	**Pr**
(Iatridou & Dionyssiotis, 2013)	**BOT**			excellent (green)		
(Liao et al., 2001)				poor (red)		
(Wilson et al., 2000)		excellent (green)				
(Darsaklis et al., 2013)	**BOT-2**			excellent (green)	excellent (green)	
(Wuang & Su, 2009)		good (yellow)		moderate (orange)		
(Lucas et al., 2013)	**BOT-2 SF**	good (yellow)		moderate (orange)		

NB: IeR = interrater IaR = intra rater, TR = test-retest, IC = internal consistency, St=Structural, Ct = content, Pr = predictive. ■ (red) = poor (ICC <.5, *r* <.3, *κ*<.6, *α* <.6), ■ (orange) = moderate (ICC = .5 -.75, *r* = .3 - .6, *κ* = .6 - .79, *α* = .6 - .7), ■ (yellow) = good, (ICC = .75 -.9, *r* = .6 - .8, *κ* = .8 - .9 , *α* = .7 - .9) ■ (green) = excellent validity/reliability (ICC >.9, *r* > 8, *κ* >.9 , *α* > .9) .

2.3.6.3 Other Product-Oriented Assessment Tools

Three studies evaluated the validity and reliability of the Körperkoordinationstest für Kinder (KTK) (Laukkanen et al., 2020; Moreira et al., 2019; Rudd et al., 2016). Two studies looked at the structural validity of the KTK, and found adequate evidence to support a one factor structure, interpreted as representing "body coordination" (Moreira et al., 2019; Rudd et al., 2016). The internal consistency of the KTK was consistently found to be good across samples in Finland, Portugal and Belgium (α ranged from .78 - .83), however, as hypothesised, there were significant differences between groups, in which children from Portugal and Belgium performed worse than Finnish participants (Laukkanen et al., 2020). Additionally, there was evidence of high inter-rater reliability (94% agreement) (Rudd et al., 2016).

Two studies evaluated the validity and reliability of the Athletic Skills Track (AST) (Hoeboer et al., 2016; Hoeboer et al., 2018). The results of both studies suggest that the AST has good test-retest reliability with intraclass correlations ranging from .8 (Hoeboer et al., 2018) to .88 (Hoeboer et al., 2016). Cronbach's alpha was used in one of these studies to examine internal consistency, with results ranging from .7-.76 for the three versions of the AST (Hoeboer et al., 2018). It is, however, important to note that only two psychometric properties from the COSMIN checklist (Mokkink et al., 2010b) were evaluated, and the quality ratings for these studies were lower than 60%.

The psychometric properties of the FMS Polygon were tested in one study (Žuvela et al., 2011), finding strong evidence for intra-rater reliability (ICC = .98). Factor analysis also explored the structure of the assessment tool, revealing four factors: object control (tossing and catching a volleyball), surmounting obstacles (running across obstacles), resistance overcoming obstacles (carrying a medicine ball) and space covering skills (straight running). These psychometric properties of the FMS Polygon, should however, be interpreted with caution, as the above study only had a quality rating of 43% (Žuvela et al., 2011).

The structural validity of the MOT 4-6 was evaluated by one study that had a high quality rating (79%), using Rasch analysis. It established four of the items had disordered thresholds and needed to be removed from the assessment (grasping a tissue with a toe, catching a tennis ring, rolling sideways over the floor and twist jump in/out of a hoop). Results also showed that with one additional item removed (jumping on one leg into a hoop), there was an acceptable global model fit for the MOT 4-6 (Utesch et al., 2016).

2.3.7 Process-Oriented Assessment Tools

Fourteen process-oriented assessment tools were identified by the pre-search as measuring FMS. Of these, eight had been evaluated for validity and reliability (described below). No research was found evaluating the psychometric properties of the: Children's Motor Skills Protocol (CMSP) (Williams et al., 2009), Instrument for the Evaluation of Fundamental Movement Patterns (Jiménez-Díaz et al., 2013), Objectives-Based Motor-Skill Assessment Instrument (Ulrich, 1983), Ohio State University Scale for intra-Gross Motor Assessment (OSU-SIGMA) (Loovis & Ersing, 1979), Preschooler Gross Motor Quality Scale (PGMQ) (Sun et al., 2010) and Smart Start (Wessel & Zittel, 1995).

2.3.7.1 Test of Gross Motor Development (TGMD)

The results of twenty-one studies which evaluated the psychometric properties of various versions of TGMD can be found in Table 6. Nine out of ten COSMIN psychometric properties were evaluated by TGMD studies. Consistently good evidence for inter-rater and intra-rater reliability was observed, with only one study finding less than ‘good’ correlations when testing sessions were video recorded (Rintala et al., 2017). One study evaluated these aspects of reliability using a Content Validity Index (CVI) and found good evidence for both inter and intra-rater reliability when testing Chilean children, with CVIs ranging from .86 to .91 (Cano-Cappellacci et al., 2016). An additional study evaluated the inter and intra-rater reliability of the TGMD (second and third editions) using percentage agreement (Field et al., 2020). Results showed agreement for inter-rater reliability was 88% and 87% for the TGMD-2 and TGMD-3 respectively, and for intra-rater reliability the percentage agreement was 98% for the TGMD-2 and 95% for the TGMD-3 (Field et al., 2020). Fewer studies examined the test-retest reliability of the TGMD, but those that did demonstrated that for the TGMD-2 (Houwen et al., 2010; Issartel et al., 2017; Kim et al., 2014; Simons et al., 2008; Valentini, 2012), a short version of the TGMD-2 modified for Brazilian children (Valentini et al., 2018) and the TGMD-3 (Allen et al., 2017; Valentini et al., 2017; Wagner et al., 2017; Webster & Ulrich, 2017) participants scored similarly when they were tested on multiple occasions. Strong test-retest reliability was evidenced with a CVI of .88 (Cano-Cappellacci et al., 2016) and Bland-Altman plots found 95% confidence intervals were within one standard deviation (Rudd et al., 2016), with a .96 agreement ratio (Lopes et al., 2018). Evidence for internal consistency was more mixed, but there was strong evidence that all items in the TGMD-3, once modified for children with ASD and visual impairments could still measure FMS as an overarching construct (Allen et al., 2017; A Brian et al., 2018). Evidence for good internal consistency of the TGMD was also found when testing children with intellectual deficits (Capio et al., 2016).

Table 6 – Validity and reliability of the TGMD

		Reliability				**Validity**
Study		**IeR**	**IaR**	**TR**	**IC**	**Pr**
(Allen et al., 2017)	**TGMD-2**					
(Barnett et al., 2014)						
(Capio et al., 2016)						
(Garn & Webster, 2018)						
(Houwen et al., 2010)						

Study		IeR	IaR	TR	IC	Pr
(Issartel et al., 2017)						
(Kim et al., 2014)						
(Lopes et al., 2018)						
(Simons et al., 2008)						
(Valentini, 2012)						
(Ward et al., 2020)						
(Valentini et al., 2018)	**TGMD-2 SF**					
(Allen et al., 2017)	**TGMD-3**					
(A Brian et al., 2018)						
(Estevan et al., 2017)						
(Maeng et al., 2017)						
(Magistro et al., 2020)						
(Rintala et al., 2017)						
(Valentini et al., 2017)						
(Wagner et al., 2017)						
(Webster & Ulrich, 2017)						

NB: IeR = interrater IaR = intra rater, TR = test-retest, IC = internal consistency, St=Structural, Ct = content, Pr = predictive. ■= poor (ICC <.5, r <.3, κ<.6, α <.6), ■= moderate (ICC = .5 -.75, r = .3 - .6, κ = .6 - .79, α = .6 - .7), ■= good, (ICC = .75 -.9, r = .6 - .8, κ = .8 - .9 , α = .7 - .9) ■= excellent validity/reliability (ICC >.9, r > 8, κ >.9 , α > .9) .

Sixteen studies evaluated the structure of the items within various editions of the TGMD, consistently finding a two factor model (locomotion and object control) for the TGMD (Evaggelinou et al., 2002), TGMD-2 (Capio et al., 2016; Garn & Webster, 2018; Houwen et al., 2010; Issartel et al., 2017; Kim et al., 2014; Lopes et al., 2018; Rudd et al., 2016; Simons et al., 2008; Valentini, 2012) TGMD-2 SF (Valentini et al., 2018) and TGMD-3 (Estevan et al., 2017; Magistro et al., 2020; Valentini et al., 2017; Wagner et al., 2017; Webster & Ulrich, 2017), as predicted by multiple studies (Capio et al., 2016; Estevan et al., 2017; Evaggelinou et al., 2002; Lopes et al., 2018). It is, however, important to note that some of these models enabled cross-loading of items (e.g. Garn & Webster, 2018), some models were hierarchical in nature (Rudd et al., 2016) and in one case a two factor model, whilst being the best fit, explained only 50% of the total variance (Issartel et al., 2017). Evidence was however found to suggest that the structural validity of the TGMD is stable across countries, with the data from populations in Greece, Brazil, Germany, the USA, South Korea and Portugal all evidencing a two factor model (A Brian et al., 2018; Evaggelinou et al., 2002; Kim et al., 2014; Lopes et al., 2018; Valentini, 2012; Wagner et al., 2017).

The content validity of the Brazilian translation of the TGMD-2 and TGMD-3 was evaluated by two studies, with stronger evidence for the validity of the TGMD-2 (CVI = .93 for clarity and .91 for pertinence) than the TGMD-3, for which the CVI for the clarity of the instructions only reached .78 (Valentini, 2012; Valentini et al., 2017). The Spanish translation of the TGMD-2 was also tested for clarity and pertinence, with results finding a CVI of .83 (Cano-Cappellacci et al., 2016). Cross cultural validity was investigated in one study that compared Flemish children with intellectual deficits to US normative data (Simons et al., 2008). It found significant differences, with large effect sizes (1.22-1.57), indicating US standardised data was inappropriate for use as a comparison within this population. Additionally, a large study based in Belgium hypothesised that Belgian children would perform similarly to US norms on locomotor scores, but that Belgian children would score lower on object control tasks. However, Belgian children had significantly worse Gross Motor Quotient (GMQ), locomotor and object control scores, thus showing that US normative data was not appropriate for this sample (Bardid et al., 2016). The COSMIN quality rating of TGMD studies did not appear to effect results, as the relative quality ratings of all studies that found excellent results only varied by 16% (54-70%) (Allen et al., 2017; Barnett et al., 2014; Capio et al., 2016; Houwen et al., 2010; Kim et al., 2012; Simons et al., 2008; Valentini, 2012; Valentini et al., 2018; Valentini et al., 2017; Wagner et al., 2017). However, predictive validity was not explored by any of the included TGMD studies.

2.3.7.2 Other Process-Oriented Assessment Tools

The psychometric properties of the FG-Compass (Furtado, 2009) were evaluated in one study, in which expert scores were compared to undergraduate student scores (Furtado Jr & Gallagher, 2012). Results showed kappa values ranging from .51-.89, with moderate levels of agreement on average (m=.71). PLAYbasic was found to have good inter-rater reliability (mean ICC= .86), and moderate internal consistency (mean α =.605) in one study (Canadian Sport for Life, 2013). Two studies evaluated PLAYfun, finding good to excellent inter-rater reliability (ICC ranged from .78 - .98) and good internal consistency (average α =.78) (Cairney et al., 2018; Stearns et al., 2019). Additionally, hypotheses testing validity and structural validity were assessed, with performance increasing with age as hypothesised, and an acceptable model fit for the proposed five factor structure (Cairney et al., 2018). Despite the quality ratings of these studies varying, (43% and 76%), the higher quality study found the more promising results (Cairney et al., 2018). One study evaluated the psychometric properties of the Teen Risk Screen (Africa & Kidd, 2013), with results demonstrating good evidence for the internal consistency (mean α = .75) and test-retest reliability (mean r = .64) of subscales. Confirmatory factor analysis (CFA) was used to evaluate the structural validity of the Teen Risk Screen, however, the analysis was not completed on the model they proposed (6 subscales). Authors claimed that due to small sample sizes, only three of the six subscales were evaluated separately, and the final three were grouped together. As this analysis did not measure the intended model, results are not detailed in this review, as it was not truly confirmatory. Get Skilled Get Active (GSGA), the Peabody Developmental Motor Scales (PDMS-2) and the Victorian FMS assessment were all used in concurrent validity studies, however, no articles were found evaluating any other aspects of validity and reliability of these measures.

2.3.8 Combined Assessments

Two assessment tools from the pre-search measure both product- and process-orientated aspects of movement: Canadian Agility and Movement Skill Assessment (CAMSA) (Longmuir et al., 2017) and PE Metrics (National Association for Sport and Physical Education, 2010, 2011). There is limited evidence for the reliability of the CAMSA with one study finding moderate effect sizes for inter-rater, intra-rater and test-retest reliability, as well as internal consistency (Longmuir et al., 2017). One other study found strong evidence for the test-retest reliability of the CAMSA (Lander et al., 2017), however that study had a lower quality rating (49% compared to 77%). One study evaluated the structural validity of PE Metrics using Rasch analysis and found good evidence that all of the items were measuring the same overarching set of motor skills (Zhu et al., 2011). It is, however, necessary to interpret this result with caution, as the COSMIN quality rating for this study was only 43%.

2.3.9 Concurrent Validity

Limited evidence was found for concurrent validity across the 23 assessment tools included in the review (see Table 7). A large proportion of the studies exploring this aspect of validity did so against either the MABC (15 studies) or the TGMD (10 studies).

2.3.9.1 Between product-oriented

The findings of studies exploring the concurrent validity of product-oriented assessment tools (top left quadrant of Table 7) mostly yielded good results, with eight out of thirteen studies finding good or better evidence for correlations between measures. Of those that didn't, one found a poor correlation (kappa = .43) between the MABC and the BOT (Crawford et al., 2001), and one study found moderate correlations between the MABC and the short form of the BOT (Spironello et al., 2010), as well the AST and the KTK, as hypothesised (Hoeboer et al., 2018). Two studies evaluated the concurrent validity of the BOT-2 complete form, and the BOT-2 short form (Jírovec et al., 2019; Mancini et al., 2020). One found poor correlations between subtests (r ranged from .08 - .45) (Jírovec et al., 2019), and the other reported moderate correlations between tasks in a sample of children with ADHD (r ranged from .12 - .98) (Mancini et al., 2020). A modified version of the KTK (with hopping for height removed) was also compared to the standard KTK, which was found to have high levels of validity (Novak et al., 2017). One study used Pearson correlations to evaluate the concurrent validity between the MOT 4-6 and the KTK, with results showing moderate correlations for children aged 5-6 (mean r= .63), as was hypothesised prior to testing (r >.6).

Table 7 – Concurrent validity of assessment tools

		Product-Oriented						Process-Oriented		
		AST	BOT	KTK	MOT 4-6	MABC	FMS Polygon	GSGA	PDMS	TGMD
Product-Oriented	AST									
	BOT		1 (poor), 1 (moderate)							
	KTK	1 (moderate), 1 (good)	1 (good)	1 (excellent)						
	MOT 4-6			1 (good)						
	MABC		1 (poor), 1 (moderate), 3 (good)	1 (good)						
	FMS Polygon									
Process-Oriented	GSGA									
	PDMS					1 (good)				
	TGMD			1 (moderate)		2 (poor), 2 (moderate), 1 (good)	1 (excellent)	1 (moderate)		2 (excellent)

NB: IeR = interrater IaR = intra rater, TR = test-retest, IC = internal consistency, St=Structural, Ct = content, Pr = predictive. ■= poor (ICC <.5, *r* <.3, *κ*<.6, *α* <.6), ■= moderate (ICC = .5 -.75, *r* = .3 - .6, *κ* = .6 - .79, *α* = .6 - .7), ■= good, (ICC = .75 -.9, *r* = .6 - .8, *κ* = .8 - .9 , *α* = .7 - .9) ■= excellent validity/reliability (ICC >.9, *r* > 8, *κ* >.9 , *α* > .9) .

In addition to the results detailed in Table 7 one study looked at the concurrent validity of assessing children using the MABC in person and via tele-rehabilitation software, with results showing no significant difference between scores, as hypothesised (Nicola et al., 2018). As well as this, the MABC and the BOT-SF had a positive predictive value of .88, with twenty one out of twenty four children testing positively for motor coordination problems also scoring below the fifteenth percentile on the MABC (Cairney et al., 2009).

2.3.9.2 Between process-oriented

These findings are summarised in the bottom right quadrant of Table 7. One study utilised the TGMD to explore the concurrent validity of the GSGA assessment tool (Logan et al., 2017). Significant differences were found between the number of children who were classified as mastering FMS versus those who had not, in which GSGA was more sensitive and classified a greater number of children as exhibiting non-mastery (Logan et al., 2017) Three studies also explored the relationship between multiple versions of the TGMD. Results revealed that children with ASD perform better on the TGMD-3 with visual aids compared to the standard assessments (Allen et al., 2017). Similarly, modified versions of the TGMD-2 and TGMD-3 were both found to be valid for use in children with visual deficits (A Brian et al., 2018). Additionally, one study showed significant differences between subtest scores on the second and third editions of the TGMD across year groups and gender, in which participants performed better on the TGMD-2 (Field et al., 2020).

2.3.9.3 Between product and process-oriented

The results comparing process and product-oriented assessment tools against each other (bottom left quadrant of Table 7) were also mixed, particularly with regards to the concurrent validity between the MABC and the TGMD, for which correlations ranged from .27-.65 (Houwen et al., 2010; Logan, Robinson, Rudisill, et al., 2014; Valentini, 2012; Valentini et al., 2014; Valentini et al., 2015). Study quality did not appear to have an effect on the size of the correlation between the MABC and the TGMD. Two studies also reported significant differences in level of agreement on percentile ranks (Logan, Robinson, Rudisill, et al., 2014; Valentini et al., 2015). The KTK and the TGMD-2 also differed significantly in terms of their classifications of children into percentile ranks (Ré et al., 2018). In addition to the studies shown in Table 7, the concurrent validity of the CAMSA and both the PLAYbasic and PLAYfun assessment tools were assessed by one study, which found moderate correlations between CAMSA and both PLAY assessment tools, smaller than was hypothesised (Stearns et al., 2019). Lastly, good cross-product/process concurrent validity was reported between the MABC and the PDMS (Hua et al., 2013), as well as the CAMSA and the Victorian FMS Assessment Tool (Lander et al., 2017) and the TGMD and the FMS Polygon, as hypothesised (Žuvela et al., 2011).

2.4 Discussion

The first aim of this chapter was to document the observational assessment tools that have been used previously within the literature to assess FMS in school-aged children. The pre-search identified twenty four assessment tools, of which nine were product-oriented, thirteen were process-oriented and two measured both product and process outcomes. The relatively small number of assessment tools available to measure all three FMS domains (i.e. locomotor, object control and stability skills) in combination (*n*=9) was surprising, particularly given the increased emphasis on the importance of stability skills in recent years (Rudd et al., 2015). Given that all three sub-components of FMS feature within the UK - P.E. curriculum (Department For Education, 2013) it will be important for any school-based screening tool to measure locomotion, object control and stability. The scarcity of comprehensive assessment tools means mean schools have limited options. However, it is possible that certain existing, and otherwise well validated and reliable assessment tools may be able to be modified to include stability skills (e.g. the TGMD).

The second aim of this chapter was to evaluate the evidence regarding the psychometric properties of the assessment tools identified in the pre-search. Surprisingly, there were no studies evaluating either the validity or reliability of eight (33%) of the identified measures. These were the: Children's Motor Skill Protocol (Williams et al., 2009), FMS Test Package (Adam et al., 1988; Kalaja et al., 2012), Instrument for the Evaluation of Fundamental Movement Patterns (Jiménez-Díaz et al., 2013), Objectives-Based Motor-Skill Assessment Instrument (Ulrich, 1983), Ohio State University Scale for intra-Gross Motor Assessment (Loovis & Ersing, 1979), Preschooler Gross Motor Quality Scale (Sun et al., 2010), Smart Start (Wessel & Zittel, 1995) and the Stay in Step Screening Test (Department of Education Western Australia, 2013). Without any evaluation of these assessments' psychometric properties, their use in schools cannot be justified, as it is impossible to ascertain whether they are able to accurately identify children who need additional support. Without proper psychometric evaluation, these assessments run the risk of being redundant and burdensome as schools may expend their already have stretched for resources on assessments that are not fit for purpose (Perera, 2020). What is particularly alarming is that the Stay in Step Screening Test, one of the assessments with no psychometric properties assessed, is already being used within schools in Australia.

Of the remaining sixteen assessment tools which did have research evaluating their validity and reliability, nine (38%) assessment tools only had a single study examining their psychometric properties. For five of these nine assessment tools, the single study only measured one aspect of validity or reliability for school-aged children. This was true for the: FG Compass (Furtado Jr & Gallagher, 2012), GSGA (NSW Department of Education and Training, 2000), PDMS (Folio & Fewell, 1983, 2000), PE Metrics (National Association for Sport and Physical Education, 2010, 2011) and the Victorian FMS Assessment Instrument (Department of Education Victoria, 2009). This level of evidence is insufficient to justify their use in schools, as research has shown that validity and reliability are separate constructs, and that the presence of one does not equate to the other being established (Drost, 2011). Nor is one aspect of validity or reliability equivocal to another.

Similarly, the four other assessment tools with only one study evaluating psychometric properties only evaluated two (Hoeboer et al., 2016) or three (Africa & Kidd, 2013; National Association for Sport and Physical Education, 2010, 2011; Žuvela et al., 2011) aspects of validity and reliability, and all of these studies had poor methodology quality ratings, of between 36%-55%. Inadequate reporting of methods reduces the utility of these findings as it becomes difficult to discern whether these results were brought about by extraneous variables which may have introduced bias into these studies. Additionally, it is important to note that any aspects of validity and reliability reported on in these studies will only have been established on one sample. It is therefore unclear how generalizable these results would be to the wider population (i.e. all school children), particularly due to small sample sizes, and the very narrow age ranges tested.

Multiple studies evaluating various aspects of validity and reliability were only found for the: MABC (*n*=37 studies), TGMD (*n*=35 studies), BOT (*n*=22 studies), KTK (*n*=10 studies), CAMSA (*n*=3 studies), the MOT 4-6 (*n*=4 studies), PLAYfun (*n*=2 studies) and the Athletics Skills Track (*n*=2 studies). The MABC was the most extensively examined assessment tool, however, the evidence for its psychometric properties was very mixed. What is perhaps more concerning, is that the studies that found strong evidence of validity and reliability (Bakke et al., 2017; Darsaklis et al., 2013; Jaikaew & Satiansukpong, 2019; Smits-Engelsman et al., 2008) had disappointingly low quality ratings which ranged between 13%-50%. Additionally, the MABC comprises three subscales, Manual Dexterity (MD), Aiming & Catching (A&C) and Balance, and the tasks within MD are not FMS, rather they are fine motor skills. With this in mind, it makes it difficult to evaluate studies that only use MABC's total score, which includes MD subscale scores in this composite score. In the context of universal screening of FMS ability, whereby fine motor skills would not be assessed, interpretation of ability based on the MABC total score does not correspond solely to assessing FMS tasks (Cairney et al., 2018; Crawford et al., 2001; Croce et al., 2001; Darsaklis et al., 2013; Ruiz et al., 2003; Smits-Engelsman et al., 2008; Tan et al., 2001). Additionally, all studies evaluating structural validity included the MD items, so it is impossible to ascertain whether the MABC would be valid to use with just the A&C and Balance subscales (i.e. as a purely FMS assessment). When evaluating the results of A&C and Balance subscales separately, studies show similar patterns of inconsistent results, but often with lower statistical significance, which indicates that the MD subscale may play a key role within establishing the MABC was a more wide ranging assessment tool that is valid and reliable for use when identifying children with motor difficulties in general, not FMS difficulties specifically. Similarly, despite showing promising signs of strong psychometric properties, the BOT (Bruininks, 1978; Bruininks & Bruininks, 2005) also includes a fine motor subscale, and is yet to be validated without the presence of this aspect. This may limit the utility of both the MABC and the BOT in universal screening programmes of FMS.

Similar issues are present with the TGMD, despite it being the assessment tool with the strongest evidence for its psychometric properties. Notably, the TGMD also does not measure stability skills. Research has established that balance is a core aspect of FMS (Rudd et al., 2015), so it is important to recognise the limitations of using tools which do not measure such skills. It seems reasonable to suggest that exploration of the FMS proficiency of children in schools should involve an assessment tool which encompasses locomotor skill, object control and balance. This would enable insights into the skills which underpin a child's ability to participate in a wide range of physical activities (Barnett, Stodden, et al., 2016), particularly as all three groups of skills are incorporated within the P.E. curriculum (Department For Education, 2013). Stability measures could be added to the TGMD, but this would also require all psychometric properties to be re-evaluated with the new items included, to enable justification of using the TGMD in school-based screening programmes.

The lack of stability skills was also evident in the AST (Hoeboer et al., 2016), CAMSA (Longmuir et al., 2017) and MOT 4-6 (Zimmer & Volkamer, 1987). Additionally the KTK (Kiphard & Schilling, 2007; Kiphard & Shilling, 1974) does not include assessment of object control skills. Thus, despite promising results for these assessment tools, albeit with the need for more extensive exploration of validity and reliability, it is difficult to recommend them for use in a school-setting in their current formats.

In particular, PLAYfun measured all three aspects of FMS, and found promising results for internal consistency, inter-rater reliability as well as structural validity. It is, however, important to note that the structural validity was not tested against the three well-established sub-components of FMS, rather a five factor structure: (i) running, (ii) locomotor, (iii) object control upper body, (iv) object control lower body, and (v) balance, stability & body control. There was a lack of information within the manuscript to justify splitting out running from other locomotor activities, and similarly why upper and lower body object control were separated. These activities are normally combined in widely accepted definitions of FMS acknowledged in the introduction to this thesis. In order to justify PLAYfun's use in schools, research would need to be done to establish whether these activities are in fact measuring different constructs. Additionally, further evidence would need to be provided to show that a more comprehensive range of psychometric properties are established.

Finally, the majority of studies included in this review utilise researchers in assessing and scoring children's FMS. It is therefore difficult to ascertain whether similar standards of reliability and validity would be retained when novices (i.e. teachers) instead used these tools to assess FMS proficiency. This is particularly important, as it would be infeasible for researchers to routinely implement universal screening programmes in schools.

The tendency for authors to be selective about the aspects of validity and reliability measured was one of the main limitations of the studies included within this review. Of the COSMIN guidelines evaluated in this review, all aspects were evaluated by a minimum of one study, but no single aspect of validity or reliability was measured by more than half of the included studies. The most commonly measured aspects of validity and reliability were inter-rater reliability (45% of studies) and structural validity (42% of studies). There was a paucity of research evaluating predictive validity (1% of studies) and cross-cultural validity using normative data sets (7% of studies). These inconsistencies in measuring different types of validity and reliability increase further the difficulty associated with making any inferences about the suitability of these tools for use in universal screening programmes within schools. Such issues are further compounded by studies recruiting specially selected samples (e.g. children with ASD or visual impairments) where there are fewer studies undertaken, and the number of participants are often limited.

Although there were no systematic reviews evaluating the validity and reliability of FMS assessment tools prior to this systematic review being undertaken, whilst under consideration at a journal, a similar systematic review was published (Hulteen et al., 2020). However, there are distinct differences between the two reviews, which mean they both offer unique contributions to the literature. This review solely explored observational assessment tools that have been used to measure FMS specifically in school-aged children. The search for the Hulteen et al. (2020) review was broader, and included pre-school children, as well as tests of ‘motor fitness’ and ‘athletic skill’, rather than pre-defined FMS assessments. Additionally, Hulteen et al. (2020) excluded children with physical and/or cognitive impairment, whereas we chose to include studies that included children with these conditions in their samples, as children with such difficulties are often seen within the mainstream school environment. Whilst the two reviews differed, the findings were largely similar. Both found the TGMD and the MABC had the most comprehensive evidence base, and that the TGMD had the strongest evidence to support validity and reliability. Additionally, both reviews shared the opinion that further work was needed to establish the psychometric properties of many existing assessment tools.

2.5 Conclusion

It is difficult to recommend any of the assessment tools identified in this review for use in schools as a method for universally screening FMS ability, in their current form. The measures with the most evidence to support their psychometric properties, which may potentially require less adaptations and/or further research to enable their use in such a capacity, were the TGMD, the BOT and the MABC.

It is, however, important to consider the feasibility of using these assessment tools in a school setting to measure the FMS of children en-masse. Indeed, issues of feasibility distinct from those relating to reliability and validity. To date there is limited understanding about teachers’ knowledge of FMS, how open they would be to such a screening initiative, and what factors may impact their engagement with school-based screening programmes. Further research is required to consult and query teachers, before recommendations can be made as to which assessment may be most suitable for this purpose. For example, certain assessments that are judged to be more valid and reliable may be viewed as less feasible than others from the perspective of the teacher tasked with implementing. In turn, this may lead to poorer motivation on the teacher’s part, and thus less fidelity in implementing such measures, which in turn might lower their validity and reliability in practice. These additional issues of feasibility will be the focus in the following chapter.

Chapter 3
Fundamental Movement Skills and their Assessment in Primary Schools from the Perspective of Teachers

3.1 Background

Chapter 2 established that the Movement Assessment Battery for Children (MABC) (Hendersen et al., 2007; Henderson et al., 1992), the Test of Gross Motor Development (TGMD) (Ulrich, 2000, 2016) and the Bruininks-Oseretsky Test of Motor Proficiency (BOT) (Bruininks, 1978; Bruininks & Bruininks, 2005) were the most valid and reliable assessment tools currently available. However, there is limited understanding about how feasible these assessment tools would be for use in universal screening programmes in schools. Whilst it is true that school-based assessments would likely mitigate issues with current assessment routes, and help to reduce healthcare inequalities, it is unclear whether such initiatives would be effective or feasible.

It is known that there are a wide variety of factors may play a role in successfully embedding new initiatives into school settings. Research has shown that in order for initiatives to be successful in primary schools, it is important to not only consider the initiative being implemented (i.e. in this case school-wide FMS assessments), but also higher-level factors (Daly-Smith et al., 2020). After consultation with school leaders and local stakeholders, the authors of this paper highlighted the importance of not only addressing the global system (i.e. implementing FMS assessments across all schools) but also considering the local system (i.e. challenges with implementation in individual schools such as generating a supportive social environment), as well as the mechanical parts of the provision (i.e. is the actual assessment tool feasible) (Daly-Smith et al., 2020).

Previously, guidelines have been proposed for judging the feasibility (mechanical parts) of school-based assessments of FMS (Klingberg et al., 2018). The authors outlined seven criteria that assessment tools should meet in order to be classified as having ‘good’ feasibility. They should:

(i) take less than ten minutes in duration per child,

(ii) only uses equipment readily available in schools,

(iii) require less than six metres squared of space for children to participate in the activities,

(iv) be product-oriented,

(v) have less than 6 items,

(vi) be administered by school staff,

(vii) require less than half a day of training.

These guidelines, however, were not co-produced in consultation with school staff, and some of them are somewhat arbitrary. For example, having a time limit guideline is logical, to ensure that FMS assessments are not burdensome for schools. However, there is a lack of evidence to support the claim that assessments that exceed this ten minutes per child threshold are categorically unfeasible. Additional guidelines allude to time pressures within schools - the number of items and time taken for teacher training. However, it would be unwise to ‘prescribe’ such values without teacher input. Furthermore, the number of items in the assessment tool does not take into account how long each activity is, and there has been a lack of consultation with teachers about how much time they would be able to spend being trained for such assessments. Similarly, there was no empirical evidence cited to demonstrate that most schools have the facilities large enough to accommodate assessment tools which take up 6 metres squared worth of space. It is likely that there may be a socioeconomic gradient with regards to how much space schools have for such activities. Finally, the authors state that assessments should be product-oriented because process-oriented assessments tend to have issues with inter-rater reliability which can lead to longer training sessions being required (Klingberg et al., 2018). However, it was evident in Chapter 2, that a process-oriented measure, the TGMD (Ulrich, 1985, 2000, 2016) had the greatest evidence to support its inter-rater reliability. Despite their largely arbitrary nature, these guidelines do provide a good starting point to facilitate discussion about the feasibility of FMS assessments with schools.

It is also not enough to consider the mechanical parts of the provision in isolation (i.e. solely the feasibility of assessments in isolation), if school-based screening of FMS is to become a reality. It will be imperative to understand, global, local, and mechanical barriers in combination (Daly-Smith et al., 2020), doing so through consultation with teaching staff, who would be tasked with implementing such initiatives. To date there is a paucity of research in this area. There have been studies which look at teacher opinions about a singular assessment tool (Lander et al., 2017) and one previous qualitative study which interviewed a small number of teachers to understand, more generally, their opinions on school-based assessments of FMS (van Rossum et al., 2018). This study found that teachers understand the importance of assessment in order to guage childrens' development, however noted that such measures need to be quick and easy to implement, and that the feedback needs to feed into lesson planning to help improve individual skills.

To date, no research has utilised behavioural science frameworks to understand teachers' ability to implement interventions, and schools' capacity to benefit from hosting such assessments, despite previous research highlighting the utility of using behaviour change theories when embedding initiatives into schools and their complex systems (Daly-Smith et al., 2020). Such a rigorous approach is imperative though if tools that may be suitable for use in schools are to be identified, intelligible suggestions for modifications to pre-existing measures are to be made, and/or development of an evidence-based, purpose-made FMS assessment tool for use in schools is to be embarked upon.

The Behaviour Change Wheel (Michie et al., 2014) is ideal for this purpose as it gives researchers a guide to understand barriers to behaviours, and subsequently match behaviour change techniques to these barriers to effectively facilitate the behaviour of interest (e.g. universal screening of FMS in schools), based on both theory and evidence. The Behaviour Change Wheel (Michie et al., 2014) is underpinned by two behaviour change frameworks, the Capability, Opportunity and Motivation Behaviour (COM-B) model (Michie et al., 2011), and the Theoretical Domains Framework (TDF) (Cane et al., 2012). The COM-B model (Michie et al., 2011) was designed to provide a more comprehensive model of behaviour change, as previous models were more selective and did not encompass all aspects of behaviour. This framework postulates that the likelihood of a behaviour occurring at an individual, or organisational level is dependent on a person's capability, opportunity and motivation to exhibit them (see Figure 10). It is also states that when all three facilitatory components are combined, then the likelihood of achieving behaviour change increases. When referring to capability, the model postulates that this can be either psychological or physical. In the context of FMS screening in schools, this relates to whether teachers have the knowledge and skills necessary to implement the assessment accurately. Opportunity refers to external factors that may make the behaviour possible or prompt it, and the COM-B model postulates that opportunity can be either physical or social. For schools, opportunity could relate to whether there is support from senior leadership for such initiatives and whether the school has the resources necessary to run the assessment. Finally, motivation can be automatic (e.g. emotions) or reflective (e.g. intentions or goals) and relates to habitual processes and analytical decision making. This could relate to how beneficial teachers believe FMS assessments to be, and the extent to which they believe that such assessments are their responsibility. It is thought that both capability and opportunity can have an influence on motivation, and that all three can influence the likelihood of enacting a behaviour. Additionally, it is stated that enacting a behaviour may subsequently impact upon an individuals' capability, opportunity and motivation to repeat said behaviour. Thus, to truly understand how to encourage the use of universal screening programmes within schools, it is essential to first establish the current capability, opportunity and motivation of teachers to host such assessments.

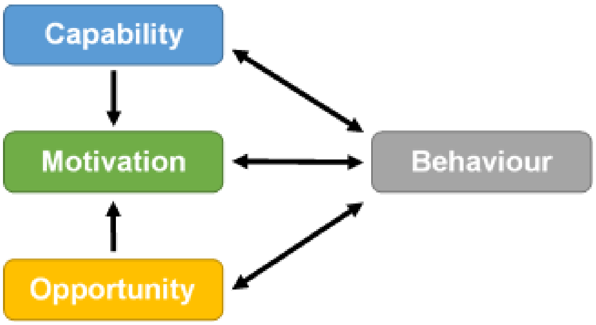


Figure 10 – Diagrammatic Representation of the Capability, Opportunity and Motivation Behaviour (COM-B) model of Behaviour Change

The TDF (Cane et al., 2012) also feeds into the Behaviour Change Wheel (Michie et al., 2014) and aligns with the COM-B categories (See Figure 11). Similarly to the COM-B, the TDF was developed by an international panel of 32 experts to be a more comprehensive framework. The authors reviewed all available behaviour change theories (33 different frameworks), and consolidated 128 constructs evident within these frameworks into 14 key factors for influencing behaviours (Cane et al., 2012). Due to having been developed by synthesising multiple frameworks, utilising both the COM-B model and TDF in combination is beneficial because it allows understanding of a wide-range of multifaceted factors influencing behaviour(s) without being selective about theories. In summary, the COM-B model and the TDF in combination with the Behaviour Change Wheel, therefore, provide a sound theoretical foundation that can be applied to understand barriers and facilitators to school-based screening of FMS proficiency.

Consequently, the aims of this chapter were to:

(i) Evaluate teacher perceptions of implementing FMS assessments in schools in line with the Klingberg et al. (2018) recommendations, understanding what additional factors might impact upon the implementation of school-based screening programmes using the COM-B model and the TDF

(ii) Utilise the Behaviour Change Wheel to make recommendations for the feasibility of school based assessments to increase the likelihood of schools implementing such initiatives.

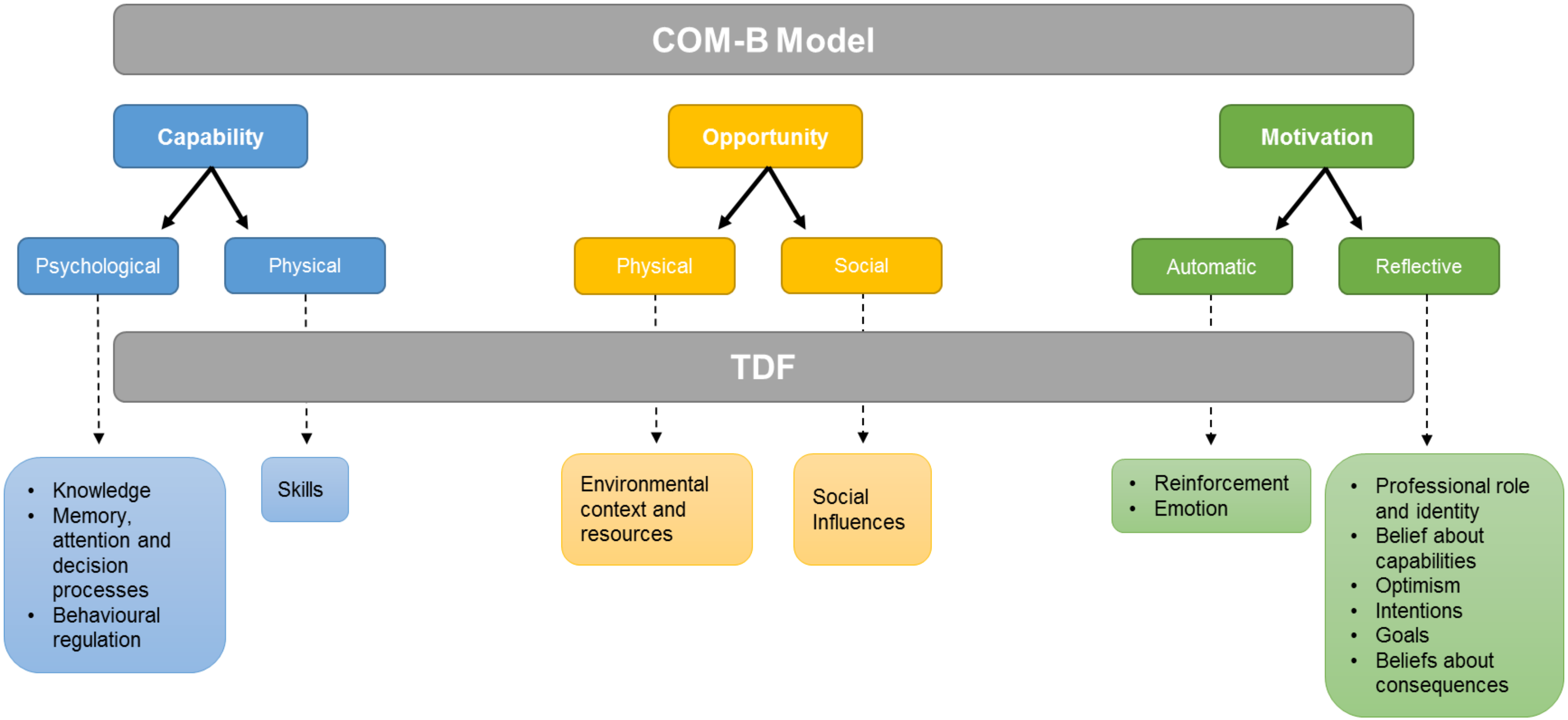


Figure 11 - Diagrammatic representation of how the Theoretical Domains Framework (TDF) components fit within the Capability, Opportunity and Motivation Behaviour (COM-B) model categories.

3.2 Methods

3.2.1 Participants and Procedure

Teachers or staff who worked in a Primary school in a role that directly supports the education of pupils (e.g. head teachers/senior leaders, teachers, teaching assistants) were invited to take part in an online questionnaire. This population was selected due to a lack of P.E. specialisation within primary schools in the (Ofsted, 2013), which means it is likely that if schools were required to universally screen FMS, the responsibility could be placed upon any member of teaching staff.

The questionnaire which had 29 items, was hosted by Qualtrics (www.qualtrics.com/uk/), and was advertised on social media (e.g. through teacher groups and forums on Facebook and Twitter) as well as through links with local schools. Participants were entered into a prize draw that gave them a chance to win one of three £20 “Amazon.co.uk” vouchers as an incentive for taking part. The questionnaire took participants approximately ten minutes to complete, and was available online between February and July 2019. Ethical approval for this study was granted by the University of Leeds School of Psychology Ethics Committee (reference: PSC-591).

3.2.2 Measure – Online Questionnaire

Demographic information was collected about participants’ gender, age, highest qualification, age groups taught, job role, years of teaching experience, type of school, country, and whether they had received training on FMS prior to completing the questionnaire. The questionnaire can be found in Appendix D.

Questions were based on previous research which explored the feasibility of FMS assessments for use in schools (Klingberg et al., 2018), were mapped alongside all six sub-elements within the COM-B model (Michie et al., 2011) and categorised in relation to the Theoretical Domains Framework (TDF) (Cane et al., 2012). There was extensive discussion amongst authors on the wording of the questions to ensure that they were both easily comprehensible and theoretically driven. Categorisations for the COM-B model and the TDF were discussed and agreed upon amongst authors. Disagreements amongst authors were resolved through consultation with a behaviour change researcher who was not involved with the design of the questionnaire. Multiple choice, scale and rank questions were used to explore primary school teachers’ opinion of their capability (e.g. ability to demonstrate FMS to pupils), opportunity (e.g. senior leadership team support for such initiatives) and motivation (e.g. how beneficial they believe knowledge of their pupils' FMS levels would be for their teaching) to assess FMS. For a full breakdown of questions included in the questionnaire, and the aspects of the COM-B model and TDF framework they align with, see Table 8.

3.2.3 Data Analysis

Patterns observed in the descriptive statistics were explored and multinomial logistic regression was used to investigate whether there were any relationships between demographic factors and responses to each question. Sex, age, highest qualification, years of teaching experience, job role, school type, and whether respondents had received training on FMS were all included in these regression models. For age, categories 4, 5 and 6 (46-55 years, 56-65 years and 66+ years) were amalgamated for this analysis because only seventeen participants were over the age of 55 years. The country in which respondents taught was not included in the regression model as the number of responses from outside of the UK was too low to test differences of opinion and draw meaningful conclusions. Age groups taught was not included in the analysis as respondents often selected more than one age group. A significance level of $p \leq .001$ was applied to mitigate for the risk of type-1 errors whilst testing multiple hypotheses. All analyses were carried out using the Statistical Package for the Social Sciences (SPSS) version 2.

Table 8 - Questionnaire items in relation to the Capability, Opportunity, Motivation and Behaviour (COM-B) model of behaviour change and the Theoretical Domains Framework (TDF)

			Construct Measured	
Variable	**Questionnaire item**	**Reponses**	**Component of COM-B model**	**Component of TDF**
Perceived knowledge	How knowledgeable do you think you are about motor skills that are defined as 'Fundamental Movement Skills'?	1)Not knowledgeable at all, 2) , 3) , 4) , 5)Extremely knowledgeable	Capability (psychological)	Knowledge
Actual knowledge	Which of the following motor skill do you think comprise 'Fundamental Movement Skills'?	Running, Handwriting , Hopping, Jumping, Using cutlery, Balancing, Dressing oneself, Throwing, Catching, Kicking, Brushing teeth, Riding a bike, Swimming	Capability (psychological)	Knowledge
Knowledge of relationship between FMS and outcomes	On a scale of 1-5, to what extent do you think the development of fundamental movement skills has an impact upon: • Academic attainment? • Participation in PA? • Mental Health?	1)No impact at all, 2)…..3)…..4)….5)Large impact	Capability (psychological)	Knowledge

	• Physical Health? • Social Relationships?			
Confidence Demonstrating	On a scale of 1-5, how confident are you that you could demonstrate the following activities: • Running between two markers for 15 seconds? • Throwing beanbags into a target box two metres away? • Hopping between two markers one metre apart? • Holding a balance (e.g. standing on one leg) whilst passing a beanbag around your body?	1)Not confident at all, 2)…3)…4)…5)Extremely Confident	Capability (physical)	Physical Skills
Confidence Assessing	On a scale of 1-5, how confident are you that yourself and one other member of staff could assess five children simultaneously in the following activities: • Running between two markers for 15 seconds?	1)Not confident at all, 2)…3)…4)…5)Extremely Confident	Capability (physical)	Physical skills

	• Throwing beanbags into a target box two metres away? • Hopping between two markers one metre apart? • Holding a balance (e.g. standing on one leg) whilst passing a beanbag around your body?			
Current FMS assessment provision in school	Do you/your school currently assess fundamental movement skill proficiency?	Yes, No, Unsure	Opportunity (physical)	Environmental context and resources
Support from senior leadership	Do you think the senior leadership team at your school would be supportive if you wanted to assess fundamental movement skill proficiency in your class?	Definitely yes, Probably yes, Probably not, Definitely not	Opportunity (social)	Social influences
Access to additional support staff resource	Would you be able to access support from another member of staff (e.g. teaching assistant) to help you deliver an assessment of fundamental movement skills to a whole class?	Definitely yes, Probably yes, Probably not, Definitely not	Opportunity (physical)	Environmental context and resources

Access to equipment	Does your school have the following equipment: • 25 beanbags? • Chalk? • A sports hall larger than 5m x 5m? • Outdoor space larger than 5m x 5m? • Stop watch? • Tape measure or metre ruler?	Yes, No, Unsure	Opportunity (physical)	Environmental context and resources
Acceptable assessment time	Over the course of a single school week, once per academic year, how long do you think is acceptable to spend assessing the fundamental movement skills of : • one child • a whole class?	<u>Per Child:</u> < 10 minutes, 10-30 minutes, 30-60 minutes, 60-90 minutes, Up to 2 hours, 2 - 3 hours, 3 hours + <u>Per class:</u> < 10 minutes, 10-30 minutes, 30-60 minutes, 60-90 minutes, Up to 2 hours, 2 - 3 hours, 3 hours +	Opportunity (physical)	Environmental context and resources

Feasibility of 2 hour start of school year assessment	Do you think you have would be able to make time in the curriculum to spend two hours at the start of the school year evaluating your class' fundamental movement skills?	Definitely yes, Probably yes, Probably not, Definitely not	Opportunity (physical)	Environmental context and resources
Time in school day most suitable to assess FMS	What time of the day would you be most likely be able to find time to assess fundamental movement skills?	Physical Education (P.E.) lessons, Core lessons (Maths, English and Science), Other lessons (e.g. Languages and Art), After school, Before school	Opportunity (physical)	Environmental context and resources
Perceptions of ability to identify children who need support through FMS assessment in schools	Do you think a school based assessment of fundamental movement skills has the ability to identify children who need additional support?	Yes, No, Maybe	Motivation (reflective)	Optimism
Perceived benefit of knowledge of pupils' FMS for teaching	On a scale of 1-5, how beneficial to your teaching would it be to have knowledge about your pupils' fundamental movement skills?	1)Not beneficial at all, 2)…3)…4)…5)Extremely beneficial	Motivation (reflective)	Beliefs about consequences
Workload stress	Do you think that assessing childhood fundamental movement skills in school would increase your workload stress?	Definitely yes, Probably yes, Probably not, Definitely not	Motivation (automatic)	Emotion

Likelihood of assessing FMS	On a scale of 1-5, if you had training and support available, how likely would you be to assess the fundamental movement skills of the children in your class?	1)Not likely at all, 2)….3)…4)….5)Extremely likely	Motivation (reflective)	Intentions & beliefs about capabilities
Peer influence	How likely would your decision regarding whether to assess the fundamental movement skills be influenced by the opinions of other teachers in your school?	1)Not likely at all, 2)….3)…4)….5)Extremely likely	Motivation (reflective)	Professional/social role and identity

NB: For confidence demonstrating, two locomotor skills were included as both have very different difficulty levels. Hopping is a more advanced locomotor skill which requires greater strength, and better vestibular and motor control. It is therefore likely to be more difficult for adults to demonstrate, particularly less fit adults, those that are overweight or those with lower limb injuries or medical conditions such as osteoarthritis.

3.3 Results

The questionnaire was online for 133 days. A total of 1074 people opened and began filling in the questionnaire; 221 people did not complete the questionnaire and their responses were therefore excluded.

3.3.1 Participants

A total of 853 primary school staff fully completed the survey and had their data analysed. Participant demographics are given in Table 9. Participants reported working across 32 different countries, with the majority working in the UK (*n*=746, 87.7%), followed by India (*n*=10, 1.2%), the USA (*n*=7, 0.8%) as well as Australia, Germany, Ireland and Malta which all had five responses (0.6%). The remaining responses spanned six continents: Africa (7 responses from 5 countries), Asia (20 responses from 15 countries), Europe (9 responses from 7 countries), North America (3 responses from 2 countries), Oceania (3 responses from 2 countries) and South America (1 response from Mexico). The mean time spent in a teaching role was 8.57 years (*SD* = 7.71, range = 2 months – 45 years 3 months). The most common responses when job role was selected as 'other' were: deputy headteacher (*n*=19, 2.2%), trainee teacher (*n*=8, 0.9%), head of year/phase (*n*=8, 0.9%), higher level teaching assistant (HLTA; *n*=7, 0.8%). When 'other' was selected for type of school, the most common responses were: special educational needs schools (*n*=9) and faith schools (*n*=5). Only 128 primary school staff (15.1%) claimed to have received training on FMS, ranging from lectures within degrees to programmes used within schools to knowledge disseminated from Physical Education (PE) leads in their schools.

Table 9 - demographic characteristics of the school workers that completed the online questionnaire

Demographic Variable	***n***	**%**
Gender		
Male	54	6.4
Female	788	92.9
Prefer not to say	6	0.7
Age		
18-25	170	20
26-35	345	40.6
36-45	203	23.9

46-55	113	13.3
56-65	17	2
66+	1	0.1
Highest Qualification		
General Certificate of Secondary Education	7	0.8
Advanced Subsidiary Level	2	0.2
Advanced Level	26	3.1
Undergraduate degree	280	32.9
Masters Degree	89	10.4
Professional Degree (e.g. PGCE)	441	52.1
Doctoral Degree	2	0.2
Job Role		
Teacher	701	82.3
Teacher Assistant	37	4.3
Headteacher	21	2.5
Special Educational Needs Coordinator	58	6.8
Other	83	9.7
Age Groups of Children Taught		
4-5 years	204	23.9
5-6 years	221	25.5
6-7 years	217	25.4
7-8 years	262	30.8
8-9 years	269	31.6
9-10 years	224	26.3
10-11 years	216	25.4
Type of School Taught In		
State	543	64.1
Private	66	7.8
Academy	212	25
Other	26	3.1

Training on FMS		
Yes	128	15.1
No	719	84.4

3.3.2 Capability

Frequencies for responses to capability questions are reported in full in Table 10.

Table 10 - Responses to questions designed to measure the capability of teachers to assess fundamental movement skills in a school setting

Variable	***n***	**%**
Perceived knowledge of FMS		
1 (Not knowledgeable at all)	225	26.6
2	322	38
3	254	30
4	43	5.1
5 (Extremely knowledgeable)	3	0.4
Knowledge of FMS		
Running	615	72.2
Handwriting	317	37.2
Hopping	553	64.9
Jumping	626	73.5
Using cutlery	351	41.2
Balancing	736	86.4
Dressing oneself	371	43.5
Throwing	554	65
Catching	544	63.8
Kicking	489	57.4
Brushing teeth	290	34
Riding a bike	219	25.7
Swimming	214	25.1
All correct	356	48.1

All correct no incorrect	128	15
All answers on the list	111	13
All incorrect	118	13.8
All incorrect no correct	1	0.1
Knowledge of relationship between FMS and outcomes		
Academic Attainment		
1 (No impact at all)	3	0.4
2	34	4
3	223	26.3
4	350	41.1
5 (Large impact)	239	28.1
Physical Activity		
1 (No impact at all)	2	0.2
2	11	1.3
3	53	6.2
4	203	23.8
5 (Large impact)	579	68.3
Mental Health		
1 (No impact at all)	2	0.2
2	31	3.6
3	141	16.5
4	371	43.5
5 (Large impact)	301	35.6
Physical Health		
1 (No impact at all)	2	0.2
2	23	2.7
3	79	9.3
4	281	33
5 (Large impact)	462	54.2

Social Relationships		
1 (No impact at all)	8	0.9
2	57	6.7
3	220	25.8
4	385	45.2
5 (Large impact)	177	20.8
Confidence Demonstrating		
Running between two markers		
1 (not confident at all)	1	0.1
2	12	1.4
3	62	7.3
4	152	17.8
5 (extremely confident)	621	72.9
Throwing beanbags to a target		
1 (not confident at all)	2	0.2
2	12	1.4
3	121	14.2
4	242	28.4
5 (extremely confident)	472	55.4
Hopping between two markers		
1 (not confident at all)	5	0.6
2	21	2.5
3	94	11
4	194	22.8
5 (extremely confident)	531	62.3
Holding a balance whilst passing a beanbag		

1 (not confident at all)	4	0.5
2	37	4.3
3	132	15.5
4	227	26.6
5 (extremely confident)	446	52.3
Confidence assessing		
Running between two markers		
1 (not confident at all)	1	0.1
2	28	3.3
3	176	20.7
4	278	32.6
5 (extremely confident)	363	42.6
Throwing beanbags to a target		
1 (not confident at all)	1	0.1
2	25	2.9
3	133	15.6
4	300	35.2
5 (extremely confident)	388	45.5

3.3.2.1 Perceived Knowledge

Perceived knowledge about FMS was relatively low, only 5.5% claimed to be either ‘very’ (*n*=44, 5.1%) or ‘extremely’ (*n*= 4, 0.4%) knowledgeable. A large proportion (68%) did believe they had ‘some’ working knowledge of FMS though. A multinomial regression showed that the final model was a better fit with demographic factors included than the intercept only model (χ^2 (80) = 233.7, p<.001). Only previous teacher training in FMS predicted a positive response to perceived knowledge (χ^2(4) = 145.83, p<.001) at the accepted significance level (see Table 11). Respondents who had received training on FMS were increasingly more likely to think that they had greater knowledge of FMS than those who had not received training. Using the response ‘not knowledgeable at all’ as the reference category, teaching staff that had received training were 29 times more likely to select ‘moderately knowledgeable’ (*OR* = 29.26, *CI* = 8.99 – 95.28), 117 times more likely to believe they were ‘very knowledgeable’ (*OR* = 117.30, *CI* = 31.08 – 442.70), and 182 times more likely to think they were ‘extremely knowledgeable’ (*OR* = 182.43, *CI* = 9.02–3691.61).

Table 11 - Likelihood Ratio Tests for teachers’ perceived knowledge of fundamental movement skills

Effect	χ^2	*df*	*p*
Intercept	.00	0	
Teaching Experience (years)	.134	4	.99
Type of School	15.41	12	.22
Training	145.83	4	<.001
Sex	18.10	8	.02
Highest Qualification	21.45	24	.61
Age Group	6.45	12	.89
Job Role	13.07	16	.67

NB: Accepted level of significance was $p \leq .001$

3.3.2.2 Actual Knowledge

When asked to select from a list of motor skills only those that are classified as FMS, 355 (42%) of the respondents selected all the correct answers (running, jumping, hopping, throwing, kicking, catching and balancing). However, 227 of this subset (63.9%) also selected at least one incorrect answer. The most commonly selected incorrect answers were ‘activities of daily living’ including dressing oneself (43.5%), using cutlery (41.2%) and brushing one’s teeth (34%). None of the demographic factors were predictors for knowledge of what skills comprise FMS (χ^2 (80) = 170.47, p=.04).

3.3.2.3 Knowledge of relationship between fundamental movement skills and outcomes

There was a fairly good understanding of the relationships between FMS and childhood development, with 69.2% of respondents (*n*= 589) agreeing that FMS had a moderate or large impact on academic attainment, 66% (*n*=562) on social relationships and 79.1% (*n*= 671) on mental health (i.e. relationships that have been well established in previous research outlined in Chapter 1). Teaching staff perceptions of the impact of FMS on physical activity and physical health were greater still at 92% (*n*=782) and 87% (*n*= 743) respectively. Multinomial regressions found that the final model was not a better predictor of responses to the impact of FMS on physical activity (χ^2 (80) = 72.33, p= .87), mental health

(χ^2 (80) = 78.55, *p*= .53) or physical health (χ^2 (80) = 68.43, *p*= .82). Analyses found that the final model was a better predictor of responses to the importance of FMS for academic attainment (χ^2 (80) = 131.22, *p*<.001), and social relationships (χ^2 (80) = 164.29, *p*<.001), however, none of the demographic variables alone significantly predicted responses for academic attainment (see Table 12).

Table 12 - Likelihood Ratio Tests for the perceived impact of fundamental movement skills on academic attainment

Effect	χ^2	*df*	*p*
Intercept	.00	0	
Teaching Experience (years)	8.12	4	.09
Type of School	15.90	12	.20
Training	3.44	4	.49
Sex	13.87	8	.09
Highest Qualification	20.44	24	.67
Age Group	17.71	12	.13
Job Role	15.05	16	.52

NB: Accepted level of significance was $p \leq .001$

For social relationships, age group predicted responses (see Table 13), in which age groups one (18-25 years) were seven times more likely to state that FMS had a ‘moderate impact’ on social relationships than a ‘very large impact’ when compared to all other age groups (OR = 7.07, CI = 2.67 – 18.75).

Table 13 - Likelihood Ratio Tests for the perceived impact of fundamental movement skills on social relationships

Effect	χ^2	*df*	*p*
Intercept	.00	0	
Teaching Experience (years)	6.52	4	.16
Type of School	24.44	12	.02
Training	2.31	4	.68
Sex	8.31	8	.40
Highest Qualification	27.84	24	.27
Age Group	31.99	12	.001

Job Role	31.33	16	.01

NB: Accepted level of significance was $p \leq .001$

3.3.2.4 Confidence Demonstrating

When asked to rate their ability to demonstrate FMS on a scale between one and five (with one indicating ‘not confident at all’ and five indicating ‘extremely confident’), 92.1% (*n*=786) were confident (selecting responses four or five) that they could run between two markers for 15 seconds. Confidence was also high for throwing into a target box (*n*= 717, 84.1%), hopping between two markers (*n*=732, 85.8%), and holding balance (*n*= 679, 79.6%). Demographic factors did not play a significant role in responses to confidence demonstrating ‘running’ ($\chi^2(80) = 81.54$, $p = .43$), ‘throwing’ ($\chi^2(80) = 80.02$ $p = .49$), ‘hopping’ ($\chi^2(80) = 79.1$, $p = .51$) or ‘balance’ ($\chi^2(80) = 36.44$, $p = 1.00$).

3.3.2.5 Confidence Assessing

When asked about confidence in assessing small groups (of five) children simultaneously for the activities described above, confidence rates remained positive, with 75.8% (*n*= 647) responding with four or five on the scale for ‘running’, 81.2% (*n*= 693) for ‘throwing’, 77.5% (*n*=661) for ‘hopping’ and 75.3% (*n*=642) for ‘balancing’. Demographic factors, again, did not play a significant role in responses to confidence assessing five children at once for ‘running’ ($\chi^2(80) = 49.49$, $p = .43$), ‘throwing’ ($\chi^2(80) = 91.55$, $p = .18$), ‘hopping’ ($\chi^2(80) = 83.58$, $p = .37$) or ‘balance’ ($\chi^2(80) = 114.14$, $p = .007$).

3.3.3 Opportunity

Frequencies for responses to opportunity questions are reported in full in Table 14.

Table 14 - Responses to questions designed to understand the opportunity for teachers to assess fundamental movement skills in a school setting

Variable	***n***	**%**
Current FMS assessment provision in school		
Yes	128	15
No	403	47.3
Unsure	317	37.2

Support from senior leadership		
Definitely yes	212	24.9
Probably yes	524	61.5
Probably not	109	12.8
Definitely not	3	0.4
Access to additional support staff resource		
Definitely yes	276	32.4
Probably yes	387	45.4
Probably not	149	17.5
Definitely not	36	4.2
Access to equipment		
25 beanbags		
Yes	696	81.7
No	77	9
Unsure	75	08.8
Chalk		
Yes	774	90.8
No	35	4.1
Unsure	38	4.5
Sports hall larger than 5x5 metres		
Yes	741	87
No	69	8.1
Unsure	37	4.3
Outdoor space larger than 5x5 metres		
Yes	832	97.9
No	11	1.3
Unsure	5	0.6

Stopwatch		
Yes	789	92.3
No	25	2.9
Unsure	37	4.3
Acceptable assessment time		
Per child		
<10 mins	393	46.1
10-30 mins	327	38.4
30-60 mins	73	8.6
60-90 mins	13	1.5
Up to 2 hours	8	0.9
2-3 hours	3	0.4
3 hours+	2	0.2
Whole class		
<10 mins	5	0.6
10-30 mins	80	9.4
30-60 mins	205	24.1
60-90 mins	166	19.5
Up to 2 hours	132	15.5
2-3 hours	113	13.3
3 hours+	132	15.5
Feasibility of two hour start of school year assessment		
Definitely yes	194	22.8
Probably yes	478	56.1
Probably not	157	18.4
Definitely not	18	2.1
Time in school day most suitable to assess FMS		
PE lessons	730	85.7
Core lessons	22	2.6
Other lessons	17	2

After school	13	1.5
Before school	20	2.3

3.3.3.1 Current Fundamental Movement Skills Assessment Provision in Schools

When teaching staff were asked whether they themselves, or their school, currently assess their pupils' FMS, 128 people (15%) in the sample responded with 'yes', 398 (47.6%) stated they did not, and 319 (37.4%) were unsure. A multinomial logistic regression found that a model with all demographic factors included was a better predictor of responses than a model without these factors ($\chi^2(40) = 129.75$, $p<.001$). Previous FMS training was the only factor to predict responses to this question ($\chi^2(2) = 36.57$, $p<.001$) (see Table 15). Teaching staff that had previously completed training on FMS were four times more likely to say that they, or their school, currently assess the FMS of their pupils (*OR*= 4.19, *CI* = 2.54 – 6.91).

Table 15 - Likelihood Ratio Tests for Whether Schools Currently Assess Fundamental Movement Skills

Effect	χ^2	*df*	*p*
Intercept	.00	0	
Teaching Experience (years)	3.61	2	.17
Type of School	4.63	6	.59
Training	36.57	2	<.001
Sex	3.83	4	.43
Highest Qualification	21.00	12	.05
Age Group	9.82	6	.13
Job Role	19.52	8	.01

NB: Accepted level of significance was $p \leq .001$

3.3.3.2 Support from Senior Leadership

A large proportion of teaching staff (*n*= 736, 86.4%) believed that senior leadership teams (SLT) in their school would 'definitely' or 'probably' be supportive if they decided they would like to assess the FMS proficiency of their pupils. None of the demographic variables were predictors of teacher perceptions of SLT support ($\chi^2(80) = 97.72$, $p= .002$).

3.3.3.3 Access to Additional Support Staff Resource

The majority of respondents believed they would ‘definitely’ (*n* = 277, 32.5%), or ‘probably’ (*n*= 389, 45.6%) be able to enlist another member of staff to help them to assess FMS proficiency in school. Only 4.2% of the sample (*n*= 36) claimed that this would ‘definitely not’ be possible. Analyses revealed that the intercept only model was not improved by including demographic factors for this question ($\chi^2(60) = 79.97$, $p = .04$).

3.3.3.4 Access to Equipment

When asked whether schools had access to basic equipment that would enable the testing of FMS, the majority of staff said their schools had ‘25 beanbags’ (*n*=696, 81.7%), ‘chalk’ (*n*=774, 90.8%), a ‘sports hall larger than five metres squared’ (*n*=741, 87%), an ‘outdoor space larger than five metres squared’ (*n*=832, 97.7%), a ‘stopwatch’ (*n*=786, 92.3%) and a ‘tape measure or metre ruler’ (*n*=827, 97.1%). None of the demographics were predictive of teacher responses to access to equipment in schools: ‘25 beanbags’ ($\chi^2(40) = 54.93$, $p = .06$), ‘chalk’ ($\chi^2(40) = 53.99$, $p = .07$), a ‘large enough sports hall’ ($\chi^2(40) = 52.67$, $p = .09$), ‘suitable outdoor space’ ($\chi^2(40) = 57.76$, $p = .03$), a ‘stopwatch’ ($\chi^2(40) = 34.97$, $p = .70$), and a ‘tape measure’ ($\chi^2(40) = 30.96$, $p = .85$).

3.3.3.5 Acceptable Assessment Time

School staff were also asked how long would be acceptable to spend assessing the FMS of one child and a whole class at the start of the academic year, with the most common responses being ‘less than ten minutes’ and ‘30-60 minutes’, respectively. Demographic factors were not predictors for acceptable time to assess FMS per child ($\chi^2(120) = 59.38$, $p = 1.00$) or for a whole class ($\chi^2(120) = 125.32$, $p = .35$).

3.3.3.6 Feasibility of Two Hour Start of Year Assessment

The majority of teaching staff said that they would be able to devote two hours at the start of the school year to assessing FMS, selecting either ‘definitely yes’ (*n*=194, 22.8%) or ‘probably yes’ (*n*= 47, 56.1%). Only 18 participants (2.1%) stated that this would ‘definitely not’ be possible. A multinomial logistic regression found that the final model significantly predicted responses better ($\chi^2(60) = 102.85$, $p < .001$). Whether or not teaching staff had received training on FMS previously was the only demographic factor that had a significant impact upon responses ($\chi^2(3) = 20.01$, $p < .001$) to this question (see Table 16). Further exploration showed that teaching staff that had received training were

62% less likely to say ‘probably yes’ than ‘definitely yes’ (*OR* = .38, *CI* = .24 - .60), meaning they had greater confidence in the feasibility of a start of year assessment.

Table 16 - Likelihood Ratio Tests for whether teaching staff would be able to spend 2 hours at the start of the school year assessing the fundamental movement skills of their pupils

Effect	χ^2	*df*	*p*
Intercept	.00	0	
Teaching Experience (years)	5.76	3	.12
Type of School	20.22	9	.02
Training	20.01	3	<.001
Sex	8.80	6	.19
Highest Qualification	17.51	18	.49
Age Group	9.79	9	.37
Job Role	8.27	12	.76

NB: Accepted level of significance was $p \leq .001$

3.3.3.7 Time in the School Day Most Suitable to Assess FMS

When asked to rank when they would most likely be able to find time to assess FMS in schools, the most popular response was ‘during P.E. lessons’ (91%). The least feasible time to assess these skills was ‘before school’, with 41.5% of the sample ranking this last. Demographic factors did not play a significant role in responses to this question ($\chi^2(80) = 76.21$, $p = .60$).

3.3.4 Motivation

Frequencies for responses to motivation questions are reported in full in Table 17.

Table 17 - responses to questions designed to measure the motivation of teachers to assess fundamental movement skills in a school setting

Variable	N	%
Perceptions of ability to identify children who need support through FMS assessment in schools		
Yes	618	72.5
No	14	1.6

Maybe	216	25.4
Perceived benefit of knowledge of pupils' FMS for teaching		
1 (not beneficial at all)	2	0.2
2	42	4.9
3	251	29.5
4	322	37.8
5 (extremely beneficial)	229	26.9
Workload stress		
Definitely yes	94	11
Probably yes	394	46.2
Probably not	330	38.7
Definitely not	30	3.5
Likelihood of assessing FMS		
1 (not likely at all)	3	0.4
2	45	5.3
3	190	22.3
4	322	37.8
5 (extremely likely)	285	33.5
Peer influence		
1 (not likely at all)	44	5.2
2	84	9.9
3	226	26.5
4	380	44.6
5 (extremely likely)	114	13.4

3.3.4.1 Perception of ability to identify children that need support through FMS assessment in schools

The majority of school staff believed that a school-based assessment would be able to identify children who need extra support (72.9% yes, 25.5% maybe), with only 1.4% of the sample claiming they did not think this would be the case. Demographic factors did not play a significant role in responses to this question ($\chi^2(40) = 67.92$, $p = .004$).

3.3.4.2 Perceived benefit of knowledge of pupils' FMS ability for teaching

When asked to rate on a scale from one (not beneficial at all) to five (extremely beneficial) how their teaching would benefit if they were aware of their pupils' FMS ability, only 5.2% of school staff responded with either one or two. The majority of respondents selected either three (29.7%), four (38.1%) or five (27.2%). Demographic factors were found to significantly predict responses ($\chi^2(80) = 143.34$, $p < .001$). Both training ($\chi^2(4) = 23.84$, $p < .001$) and job role ($\chi^2(16) = 55.97$, $p < .001$) were predictive of the way respondents answered (see Table 18). Teachers who had previously received training were more likely to believe that their teaching would be benefitted by knowledge, and similarly, teachers were more likely to perceive such benefits than other members of school staff.

Table 18 - Likelihood Ratio Tests for perceived benefit of knowledge of pupils' fundamental movement skills for teaching

Effect	χ^2	*df*	*p*
Intercept	.00	0	
Teaching Experience (years)	6.54	4	.16
Type of School	21.41	12	.05
Training	23.84	4	<.001
Sex	8.28	8	.41
Highest Qualification	25.87	24	.36
Age Group	16.04	12	.19
Job Role	55.97	16	<.001

NB: Accepted level of significance was $p \leq .001$

3.3.4.3 Workload Stress

When asked whether assessing FMS in schools would increase workload stress, over half of the respondents selected 'definitely yes' ($n = 94$, 11%) or 'probably yes' ($n = 394$, 46.2 %). Only 30 participants selected 'definitely not' (3.5%). Demographic factors did not have a significant effect on the regression model ($\chi^2(60) = 87.21$, $p = .01$).

3.3.4.4 Peer Influence

When asked whether their decision to assess FMS would be influenced by other staff in their school, over half of the respondents selected either 'extremely likely' ($n = 114$, 13.4%) or 'somewhat likely' ($n = 380$, 44.6%), and only

15.1% of participants selected that it would be ‘not likely at all’ (5.2%, *n*=44) or ‘somewhat unlikely’ (9.9%, *n*=84) to influence them. Demographic factors did not play a significant role in how participants responded to this question ($\chi^2(80) = 109.59$, $p = .02$).

3.3.4.5 Likelihood of Assessing FMS

When asked on a scale of one (not likely at all) to five (extremely likely) how likely they would be to assess the FMS proficiency of their pupils if they had appropriate training and support available, the response was largely positive, with 71.8% of the sample choosing four or five, and thus being likely to implement such an initiative. Only 5.7% of the sample (*n*=47) selected one or two, indicating they would be unlikely to assess. Demographic factors did not have a significant effect on the regression model ($\chi^2(80) = 97.50$, $p = .09$).

3.4 Discussion

The first aim of this chapter was to establish teacher perceptions of feasibility, and more specifically, to see if they aligned with the Klingberg et al. (2018) guidelines. The second aim was to improve understanding of what other factors may affect the viability of school-based assessments of FMS by framing questions in line with two prominent behaviour change theories - the COM-B model (Michie et al., 2011) and the TDF (Cane et al., 2012). Using behaviour change will help to unpack why, in spite of a large appetite for use of such assessments in schools, they were not already being implemented on the whole. Indeed, only 15% of respondents believed pupils’ FMS was currently being measured in their schools.

When focusing on psychological capability alone, results revealed that over a quarter (26.6%) of teachers had no perceived knowledge about FMS and a greater proportion still (38%) believed they had low levels of knowledge about these skills. This is in line with recent qualitative research which suggests that early years educators often do not have the knowledge about FMS to help with the development of FMS (Dobell et al., 2021). It is therefore perhaps unsurprising that only fifteen percent of the sample managed to correctly identify all FMS from a list of generic motor skills, without also selecting any incorrect answers. Interestingly, this is an equivalent proportion to those that had also received training on FMS previously. The lack of training that school staff receive to help support their pupils’ development of FMS is worrying, considering the wide-ranging impacts these skills have on other aspects of childhood development (Barnett, Stodden, et al., 2016). This has been brought to the attention of the Government in the UK previously, with the All Party

Parliamentary Group (APPG) on Fit and Healthy Childhood recommending that teaching staff should be receiving comprehensive training to ensure that children can develop these skills in a safe and effective manner (Clark et al.).

The Klingberg et al. (2018) feasibility criteria also state that teaching staff should receive training which takes less than half a day in duration, to enable them to assess the FMS proficiency of their pupils. Whilst the specific constraints of teacher training were not evaluated by this questionnaire, it is clear that such development opportunities will be crucial to ensure understanding of what FMS are, as well as how to implement the assessment tool. It will also be important to ensure that training includes information on the role of FMS plays in childhood development, as although a large proportion of teaching staff were aware of the association with physical health and physical activity, which is in line with previous research (van Rossum et al., 2018), teachers were less aware of the wider implications these skills have for socioemotional development and academic attainment.

Physical capability did not appear to be a specific barrier to hosting FMS assessments in schools, with over 75% of teaching staff surveyed confident that they could demonstrate and assess running, throwing, hopping and balancing. It is, however, important to note that physical capability could not be truly measured through the use of a questionnaire (rather the results reflect perceived ability). Additionally, this still leaves one in four teachers as potentially not feeling confident enough to demonstrate these skills to their pupils. Whilst this is not the majority, it is still a rather large proportion which could have logistical implications for schools. It is possible that having teachers that are not confident demonstrating FMS could lead to issues with implementation fidelity. It will therefore be important that such capability is ensured, through the use of active training sessions, before teachers are allowed to implement FMS assessments.

With regards to physical opportunity, one of the aspects of the Klingberg et al. (2018) guidelines that was evaluated was the duration of assessments. Their proposal was that assessments should take less than ten minutes per child, a suggestion they did not substantiate with evidence. The teaching staff that completed this questionnaire did though concur with this idea, and when given a number of choices, the most acceptable timeframe to assess a single child was indeed less than less than ten minutes, with 46.1% of the sample selecting this option. This questionnaire also asked about the duration for a whole class, because to ensure that children are not missed by the socioeconomic gradient seen within healthcare services, universal screening in schools will entail assessing every child, and the most likely format of such assessments would therefore be within a class setting. The most acceptable timeframe to assess a class of thirty children was between 30-60 minutes. Finally, a majority (78.9) of teaching staff believed that they would likely be able to spend two hours at the start of the school year to assess a whole class.

The brevity of the assessment time limits deemed feasible by teachers, likely reflect teachers feeling progressively more worried about having sufficient time to cover the ‘core’ curriculum (i.e. English, Maths and Science) (Routen et al., 2018), which has led to P.E. lessons being shortened, or even completely cut in some cases (Rumsby, 2015) in order to accommodate for extra time to deliver content which will be assessed by OFSTED (Rudgard, 2018). This has been highlighted more recently, in schools’ response to the COVID-19 pandemic, whereby sports halls were being used as extra classrooms to enable social distancing (McBride, 2020). With many respondents (85.7%) feeling that P.E. lessons were the ideal time within the school day to assess FMS, the limited time deemed feasible to allocate to such assessments is therefore logical.

Of the three assessments that showed the most promising psychometric properties in Chapter 2, all would require a longer duration than teachers are willing to spend assessing FMS, both for an individual child, as well as a class. The TGMD (Ulrich, 1985, 2000, 2016) usually takes between 30-40 minutes per child to assess both locomotor and object control skills, a duration which was thought to be acceptable for a whole class, rather than a single child. Additionally, as was noted in Chapter 2, further activities would need to be added to the TGMD to ensure it includes stability skills so that it encompasses all aspects of FMS which are covered by the curriculum. Adding further tasks would only increase the duration of this assessment. Similarly, the MABC (Hendersen et al., 2007; Henderson et al., 1992) and the BOT both take between 45-60 minutes to assess a child’s motor ability and are designed to be delivered one-to-one. Chapter 2 established that both of these assessments also include fine motor skills, which could be removed for the purpose of universal screening of FMS ability. This would likely save some time, however it is unlikely that enough time would be saved from these assessments to reduce their administration time to less than ten minutes, in order for them to be classed as feasible.

Questions relating to physical opportunity also included access to equipment, which was also a guideline set out by Klingberg et al. (2018). They stated that assessments should only utilise equipment that is readily available in schools, however they did not provide any examples of such equipment. This questionnaire looked at the availability of simple, inexpensive equipment that can typically be found within schools and could be used to assess FMS. Over

80% of the teaching staff that responded to this questionnaire were confident that their school had 25 beanbags (81.7%), chalk (90.8%) and a stopwatch (92.3%). It is, however, important to note that the questionnaire did not ask about all the different types of equipment needed for MABC, TGMD & BOT, so it is difficult to know whether these are truly feasible in terms of the resources they require. On the other hand, the nature of these assessments requires specific equipment which make it even more unlikely that schools would find these assessments feasible, given they would have to invest in purchasing them. For example, the MABC (Hendersen et al., 2007; Henderson et al., 1992) requires you to have specialist mats, which have target circles on, for hopping tasks. Similarly the BOT requires you have a balance beam and to use the TGMD (Ulrich, 1985, 2000, 2016) you need to have specifically sized equipment, such as a 4 inch ball for catching. Whilst such equipment enables the delivery of these assessments, it is important to factor in the cost, as recent reports have projected that schools will feel increasing pressure on their budgets (Perera, 2020). With this in mind, it is noteworthy that the MABC-2 costs £1,172, the gross motor subscale of the BOT-2 costs £545 and the TGMD-3 costs $150, however the price of the TGMD does not include the specific equipment required, so it is likely that schools would incur additional costs resourcing these.

Space required was also evaluated under Physical Opportunity, in alignment with the Klingberg et al. (2018) guidelines, which state that assessments should be able to be undertaken in the corner of a room, or in less than six metres of space. Again, this guideline was unsupported by evidence in the original article, however, teaching staff that responded to this questionnaire on the whole agreed that they had five metres squared worth of suitable space either indoors (87%) or outdoors (97.9%). It is notable that two of the most psychometrically sound assessments require more space than this. For the TGMD, over 18 metres of ‘clear space’ is needed for the running task alone, similarly the BOT requires a space of 18 metres by 4 metres. The MABC would be able to be completed within the Klingberg et al. (2018) space parameters, however, some activities require a suitable wall (i.e. even surface, clear of mountings) to be able to throw a ball against, which may be problematic for some schools. The final Physical Opportunity question that was asked related to the availability of another member of teaching staff to aid with FMS assessments. This was included, as it is likely that for universal screening of FMS to be feasible with regards to time, assessments will need to be done on a class level. Research has shown that nearly a quarter of P.E. lessons can be spent on class management (Bevans et al., 2010), so having additional support to aid behaviour management and speed up the process of assessment may be beneficial. Only a small proportion of teachers (4.2% of the sample) thought that this would definitely not be possible. It is, however, conceivable that this may also relate to social dynamics within the school.

Only one question was asked in relation to social opportunity, because there was only one aspect of the TDF that aligned with this COM-B category (social influences). Teaching staff were asked whether they believed that the Senior Leadership Team (SLT) at their school would be supportive if they wanted to assess the FMS proficiency of their pupils. A large proportion believed SLT would encourage such initiatives (86.4%). The backing of new initiatives by SLT has been found to be crucial for implementation in previous research (Taylor et al., 2011), so it is promising that teachers believe this new provision would be supported.

The Reflective Motivation of teachers was generally high, with respondents' believing that there is a relatively strong benefit to assessing FMS in schools (with over 65% of the sample selecting 4 or 5 on the scale, and only 5% selecting 1 or 2), and with 72.5% believing that such assessments would help to identify children that need additional support. Additionally, a large proportion said they would be very or extremely likely to assess the FMS of their pupils if they were given appropriate support. There were, however a number of barriers identified within motivation, which will be important to address, including that teachers' decisions as to whether to assess FMS would likely be influenced by the opinion of other members of teaching staff in the school (peer influence). Social dynamics have been found to play a crucial role in both teaching practices (Supovitz et al., 2010), and the adoption of initiatives in schools, with a co-designed model suggesting that it will be crucial to have a 'whole school ethos' to enable successful implementation (Daly-Smith et al., 2020). Additionally, within Automatic Motivation, when teachers were asked whether implementing FMS assessments in schools would increase workload stress, over half of the sample believed that it 'definitely' (11%) or 'probably' (46.2%) would. This is perhaps unsurprising given the literature detailed above regarding time pressures in schools (Rudd et al., 2015; Rudgard, 2018).

The results of this study enabled the refinement and improvement of Klingberg et al.'s original guidelines for feasibility, leading to the following amendments:
(i) assessments should be quick to implement, be that either less than ten minutes per child, or between 30-60 minutes per class

(ii) assessments should only utilise equipment that is readily available in schools, such as beanbags and chalk, or should provide schools with such equipment at no additional cost

(iii) space constraints in schools mean that the FMS of children should be able to be assessed within a small (≤5 m^2) space, either indoors or outdoors.

These recommendations, if adopted, will increase the likelihood of the adoption of school-based FMS assessments long term. There were however three aspects of the Klingberg et al. (2018) guidelines which were not directly assessed using this questionnaire: teacher training time, person implementing the assessment and the type of assessment tool. Klingberg et al (2018)'s original guidelines state that teaching staff should be able to run the assessment, with less than half a day of training. To enable universal screening in schools on a regular basis (e.g. annually), it will be essential that assessments can be done 'in house' without outside guidance from researchers or healthcare professionals, and these results also showed that teachers would likely be able to access additional support for such assessments. Given time constraints within schools, and the pressure on workload stress that teaching staff believed that assessing FMS in schools would bring about, this guideline should be considered sensible. Two of these guidelines can therefore updated with the following modifications:

(iv) assessments should be implementable by two members of teaching staff

(v) teaching staff should require minimal training to enable them to assess the FMS of their pupils (maximum of half a day).

It is important to note that none of the three assessment tools found to have the strongest psychometric properties (TGMD, BOT & MABC) meet these criteria, as they are all designed to be implemented by researchers or trained healthcare professionals, who have had substantially more training.

With regards to the type of assessment used, Klingberg et al. (2018) state that school-based assessments should be product-oriented (e.g. MABC and BOT), as process-oriented measures (e.g. TGMD) can have poor inter-rater reliability, citing one study (Barnett et al., 2014). The authors then infer that this may mean that training will take longer. Chapter 2, however, showed that ten out of fifteen studies that tested inter-rater reliability for the TGMD found excellent results, four found 'good' reliability and only one found 'moderate' evidence. On the other hand, it is notable that these studies did not evaluate the inter-rater reliability of novice scorers, which teachers would be. Due to the lack of clarity around this point, it is therefore important to further consider the advantages and disadvantages of both types of assessment type before declaring which is the most suitable for use to universally screen FMS ability in schools.

Although both types of assessment measure FMS, they measure it in very different ways. Product-oriented assessments measure the outcome of FMS, for example how far a child can run in ten seconds, whereas process-oriented focus on how FMS are executed, based on a pre-defined set of expert movement patterns, such as whether a child’s knees are at a ninety degree angle to the floor when running. Herein lies the main difference, the focus; function versus form. Klingberg et al. (2018) argue that training for process-oriented assessment may therefore take longer, due to the teachers needing to have a comprehensive understanding about each of the specific phases of all FMS to enable them to make real-time subjective decisions about whether the child is adhering to pre-set criteria relating to ‘proper form’. This is likely true, but process-oriented assessments do provide more information about the specific problems children have with FMS.

Despite this, the level of knowledge it requires teaching staff to have is potentially too great, given that there is a paucity of specialist P.E. teachers in the UK (Ofsted, 2013). Furthermore, the general lack of knowledge about what FMS are, as demonstrated by the results in this chapter, suggests training teachers to this level of understanding could require substantial additional investment. It is, important to also consider the purpose of universal screening in schools, which would be to help identify children that are struggling with FMS, who would be under-identified through current referral routes, and thus may struggle to lead a healthy and fulfilling life. For a child to be able to participate in physical activities, they do not necessarily need to be able to follow expert movement patterns. For example, to enable a child to play catch with their friends, they need to be able to throw to a target and move their hands in space to receive the ball back, both of which can be measured using product-oriented measures. It does not matter for participation how a child is completing those movements. Finally, it is noteworthy that product and process oriented measures do not correlate very well (see Chapter 2), and that they in fact tell us different things about motor development (True et al., 2017).

As NHS services also tend to use product-oriented measures (namely the MABC) to assess motor difficulties, it would therefore be sensible for screening tools to also be product-oriented (i.e. would highlight similar children as having difficulties). In turn, this would potentially reduce the burden that children sent to healthcare services to receive more comprehensive evaluations of their difficulties from already stretched services. For this reason, the final feasibility criteria proposed in this thesis concurs with Klingberg et al.'s original guideline that:

(vi) school-based assessments of FMS should be product-oriented.

Considering the six feasibility criteria outlined above, it is clear that none of the three most psychometrically sound FMS assessments (as identified in Chapter 2) are feasible for use within universal screening programmes of FMS ability in schools. The TGMD meets none of these guidelines, and the BOT and the MABC only meet one (type of assessment) or two (space requirements and type of assessment) respectively. There were 4 other product-oriented assessment tools identified in the systematic review (Chapter 2) that had some level of evidence to support their psychometric properties: the AST (Hoeboer et al., 2016), the FMS Polygon (Žuvela et al., 2011), the KTK (Kiphard & Schilling, 2007; Kiphard & Shilling, 1974) and the MOT 4-6 (Zimmer & Volkamer, 1987). Three of the assessments don't include one aspect of FMS, either object control (KTK) or balance (AST and MOT 4-6), which makes it difficult to justify their use in schools, particularly given the limited evidence to support their psychometric properties even without the addition of these skills. Additionally, the MOT 4-6 is most often used in pre-school, so falls outside the remit of screening in Primary schools. Finally, there was only one study evaluating the FMS Polygon, which had a low study quality rating (Žuvela et al., 2011). Moreover, the FMS Polygon only assesses speed of movement, rather how well the movements are performed, which arguably limits the value of the results obtained by the assessment. Finally, it is important to emphasise that none of these assessments meet all six criteria outlined in this chapter. It is therefore impossible to recommend any pre-existing measures of FMS for use in school-based screening programmes. Instead, it is evident that a new, purpose-made assessment will be required to ensure feasibility, and therefore increased likelihood of uptake, to enable all children have an equal opportunity to receive support for FMS difficulties.

Moreover, in order to improve the chances of schools universally screening pupils' FMS ability, it will be vital for any new assessment tool to address the barriers that were identified in this chapter. The Behaviour Change Wheel (Michie et al., 2014) offers a unique opportunity to pair barriers to initiatives with behaviour change techniques, and thus provides a great platform to understand how assessments can be designed to match the constraints of the school environment. The first barrier identified was with regards to Psychological Capability, in that there was a lack of knowledge amongst teaching staff about what exactly FMS are and the wide-ranging impacts these skills have on other aspects of childhood development (Barnett, Stodden, et al., 2016). It was also evident that, generally, FMS are not included within teacher training curriculums. The benefits of training could be seen throughout responses, as those with prior training were more likely to already assess FMS in schools and think that there would be time available to spend two hours at the start of the school year assessing the FMS of their pupils. When considering shortcomings in Psychological Capability (COM-B) or knowledge (TDF), the Behaviour Change Wheel (Michie et al., 2014) recommends education and training interventions. In addition, behaviour change techniques are also suggested to be included within education and training interventions to facilitate their success, including adding objects to the environment to facilitate the performance of the behaviour (assessing FMS). One example of this would be developing a manual for teachers to help them retain information from the training session. Providing additional “take home” resources, such as manuals has previously been found to be highly effective for teacher-led FMS interventions when used alongside face-to-face training (Brian et al., 2017). Additionally, teachers should be given information about the health consequences of having poor FMS in childhood including higher physical inactivity in childhood (Jones et al., 2020; Logan, Robinson, Getchell, et al., 2014; Xin et al., 2020) and throughout the lifespan (Sacko, 2020), as well as low levels of fitness and higher incidence of overweight and obesity (Cattuzzo et al., 2016). It is therefore clear that for any school-based FMS assessment to be successful, it will need to include comprehensive, but concise (less than half a day) training for teaching staff.

The two remaining barriers to school-based assessments that were identified fell within motivation – workload stress and peer influence. Workload stress falls within Automatic Motivation (COM-B) and Emotions (TDF). For such categorisations, the Behaviour Change Wheel (Michie et al., 2014) suggests similar interventions; modelling (providing an example of what to aspire to) and persuasion (inducing positive feelings to stimulate action). The paired behaviour change technique to improve the likelihood of the success for these intervention is social support. One way this could be achieved is through the use of face-to-face group training, to help create an understanding of FMS within the school environment and how, teaching staff collectively, can play an important role in identifying children with difficulties. This may play a particularly important role within schools that do not have specialist P.E. teachers, which is the case in many schools in the UK (Ofsted, 2013). This group-based approach may help them lean on each other for support when learning new concepts. Additionally, research has shown that having senior leadership support new initiatives within schools is beneficial to teachers’ training and development (Taylor et al., 2011), so having SLT present for training may prove crucial. Finally, to ensure that social and emotional support is available to teachers implementing FMS assessments, schools should be encouraged to set up an ongoing support network, which provides a safe place for teachers to highlight concerns and discuss strategies. Research has shown the importance of using a whole school approach to promoting and sustaining new initiatives within schools (Daly-Smith et al., 2020), so ensuring teachers have ample support, from all levels within the school, will be crucial.

Therefore, alongside the guidelines for feasibility outlined within this chapter, school-based assessment tool should also consider utilising the following behaviour change interventions and techniques to increase the likelihood of being acceptable, and therefore utilised in schools: (a) training should be done face-to-face, with SLT present; (b) manuals should be provided to schools to encourage an understanding of FMS and their importance, as well as act as a prompt on how to accurately implement and score the activities within the assessment; (c) teachers should set up a network of support to share experiences, ease workload stress and encourage a healthy working environment. For an overview of barriers and facilitators to school-based assessments, as well as their paired behaviour change techniques, see Figure 12.

3.4.1 Limitations

It is important to recognise that questionnaires are subject to response bias. In particular, the way in which the survey in this chapter was advertised may have had an impact upon the type of participant that responded. Specifically, this questionnaire was advertised through social media. The first issue related to this is that the demographic span on such sites is generally not conducive to all ages, and thus tends towards recruiting younger participants. This was evident in this study, as over 60% of participants were aged between 18 and 35 years old. Additionally, an individual’s personality traits can influence their use of social media site, with research demonstrating that Facebook users are often more extrovert and agreeable than general internet users (Rife et al., 2016). Moreover, it is known that it is difficult to verify people’s identities on social media sites (King et al., 2014), so although the adverts were placed on teacher groups on Facebook, to be accepted into these groups, all you need to do is write a brief description of your teaching experience, which could easily be fraudulent.

On the other hand, it is thought that the benefits of recruiting online, including the likelihood of gathering more data, outweigh these limitations (King et al., 2014). Additionally, research has shown that online research can yield similar results to face-to-face studies with the same parameters (Casler et al., 2013). The questionnaire was also advertised locally, through Bradford Schools Online, a website through which schools in the Bradford District area receive news. Targeting this group could have potentially led to bias, as Bradford as a location poses somewhat unique challenges to its schools. For example it has some of the richest and poorest neighbourhoods in the country, as well as an eclectic mix of cultures and ethnicities (Dickerson et al., 2016). However, location data was gathered when participants completed the questionnaire, and only 12% of responses were from the Bradford area, so it is likely that there was a wide enough range of responses to mitigate for these biases.

In addition to this, the questionnaire was optional, and it is therefore likely that those willing to participate had some interest in FMS or motor skills, and their assessments in schools prior to taking part. This could mean that the responses gathered may be more positive than the views of teaching staff more generally. Moreover, this questionnaire was incentivised, teachers were entered into a prize draw to win one of three Amazon vouchers. Research has shown that incentives are effective in increasing the response rate (Laguilles et al., 2011), and that incentives similar to those used in this study do not impact upon study quality (Toepoel, 2012). However, it is important to note that women are more likely to respond to online questionnaires with incentives than men (Becker et al., 2019; Boulianne, 2013), which was evident in this study with 92.9% of the sample identifying as female. It is, however difficult to ascertain whether this is disproportionate in relation to the gender split in primary school teaching, as there is limited published information about this.

There were also a number of limitations to the questionnaire itself. One example of this is that it was not possible to truly measure the physical capability of teachers, as their skills were not able to be evaluated. Physical Capability questions therefore related to teachers' *perceived* capability to demonstrate and assess the skills outlined in the questionnaire. Research has shown that young adults (a large proportion of the sample in this questionnaire) are no more accurate than young children when evaluating their own competence (De Meester et al., 2020), and thus, it is possible that teachers' over-estimated their ability levels. It will therefore be imperative that training sessions be comprehensive, to ensure that teachers have the understanding and ability to run FMS assessments effectively. Secondly, teachers were not given a detailed description about what was meant for each of the FMS when they were asked to rank how able they would be to demonstrate and assess them. One example of this is hopping, it was not specifically stated whether this meant single leg hopping, and it is possible that this question was misconstrued to mean bunny hopping.

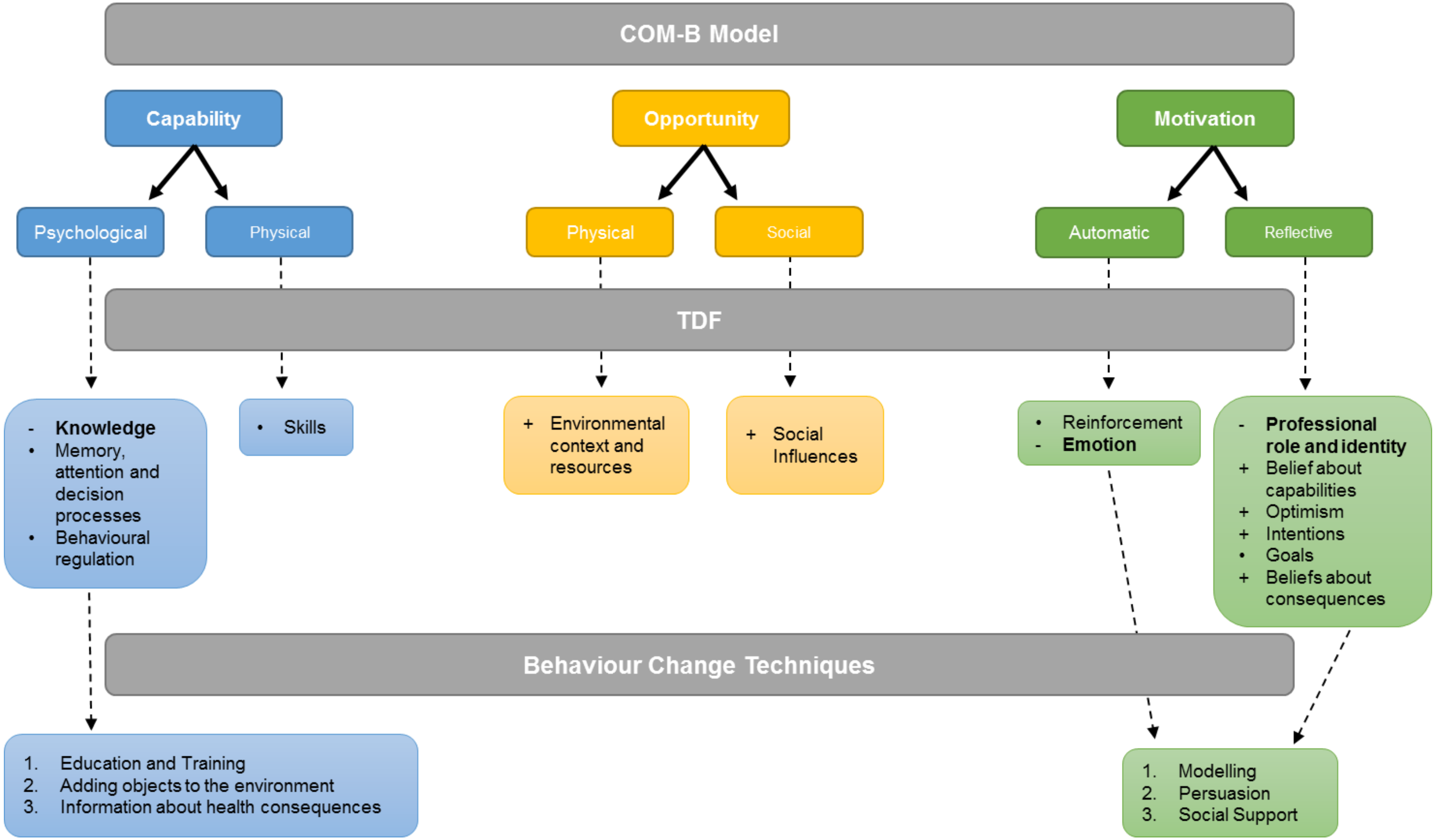


Figure 12 - The barriers and facilitators to school-based assessments, and the paired behaviour change techniques to improve the uptake of universal screening in schools.

Thirdly, this questionnaire did not include any questions regarding the extent to which teachers would be able to interpret the outcomes of FMS assessments. This was not included for a number of reasons. Firstly, this parameter was not within the Klingberg et al. (2018) feasibility guidelines and secondly, the outcomes of different assessment tools vary massively, and thus it would be difficult to measure this. Despite this, it will be crucial for any school-based assessment to ensure that teachers are equipped to understand and respond to the results they may obtain. Finally, the validity and reliability of this questionnaire was not tested prior to its use in this study. However, the research team piloted the questionnaire to ensure that everything worked as it was supposed to, and all questions were discussed at length amongst the team to ensure that they were theoretically driven, relevant for teachers and aligned with both FMS and behaviour change literature.

3.4.2 Conclusion

The results from this online questionnaire confirmed a large appetite for FMS assessments in primary schools. However, currently, such assessments are not commonplace. It is likely that the lack of action relates to a lack of capacity within schools to assess FMS using current measures due to time, equipment, space and monetary constraints along with social and workload pressures. A new assessment tool is therefore needed, to enable the implementation of universal screening in primary schools within the UK. Based on the results of this questionnaire, the recommendations that need to be adhered to in the development of such a new measure are as follows:

(i) assessments should be quick to implement, be that either less than ten minutes per child, or between 30-60 minutes per class.

(ii) assessments should only utilise equipment that is readily available in schools, such as beanbags and chalk, or should provide schools with such equipment at no additional cost.

(iii) space constraints in schools mean that the FMS of children should be able to be assessed within a small ($\leq 5\ m^2$) space, either indoors or outdoors.

(iv) assessments should be implementable by two members of teaching staff.

(v) teaching staff should require minimal training to enable them to assess the FMS of their pupils (maximum of half a day).

(vi) school-based assessments of FMS should be product-oriented.

It will also be essential for any new assessment tool to utilise the following paired behaviour change techniques to help overcome the barriers identified in this study:

(a) face-to-face training with SLT present

(b) teachers should be provided with informative and easy to use manuals

(c) teachers should be encouraged to set up a network of support.

Chapter 4
Development of FUNMOVES

4.1 Introduction

Chapter 3 established that none of the pre-existing FMS assessment tools are feasible for use by teaching staff in schools, which limits their utility for universal screening programmes. In addition, those which were more feasible for use in schools did not have strong psychometric properties to support their use in these settings (as seen in Chapter 2). It was therefore evident that a new assessment tool would need to be developed if universal screening in schools is going to become a reality.

Chapter 2 established the importance of validity and reliability for tools that are going to be used in such scenarios. One psychometric property that is crucial to evaluate during the initial development of an assessment tool is structural validity. Structural validity refers to the extent to which an assessment tool measures what it was designed to measure. It is crucial that school-based FMS assessment tools measure all relevant domains of FMS for a number of reasons. Firstly, as the P.E. curriculum within the UK focuses on FMS ability in Key Stage One (Department For Education, 2013), the activities need to actually measure FMS for teachers to be able to make meaningful inferences about pupils' abilities in this aspect of the curriculum. Secondly, it is important that the activities will pick up children with difficulties with FMS, and not other problems, so that the support given to children afterwards is appropriate and will help them lead a healthy and fulfilling life. Referring the wrong children to physiotherapists and occupational therapists will only increase the pressure on these services which are already under pressure (Finch, 2015).

There are two main ways that structural validity can be measured: (i) Classical Test Theory (CTT) or (ii) Item Response Theory (IRT). Historically, CTT has been used more frequently and is thought to be the more simplistic of the two methods (Progar et al., 2008). In CTT the observable difference between children's FMS scores on an assessment tool would be assumed to be caused solely by individual differences in FMS abilities (Magno, 2009). CTT is often referred to as 'true score theory' for this reason. CTT analyses work under the premise that any external variables are constant or random in their response variability. In CTT models, the observed score (TO) is comprised of true scores (T) and error scores (E), which are independent of each other (TO = T + E).

Standard error is assumed to be the same across participants within CTT analysis, and often it is presumed that this error is random, with a normal distribution (Magno, 2009). This error value is used to evaluate how accurate the results of an analysis are (Magno, 2009). As it is assumed that assessment tools are imprecise, standard error values are used to calculate confidence intervals around the observed score which are then used to demonstrate the upper and lower bound of the ‘true’ score (Kaplan & Saccuzzo, 1997). CTT analyses, such as factor analysis, are often used to establish the structural validity of FMS assessment tools.

There are, however, a number of issues that present themselves when using factor analysis to establish a case for structural validity. Firstly, to run a factor analysis it requires a complete dataset. Any missing data has to be either inputted by indirect methods (e.g. estimation) or incomplete persons or items data have to be excluded. Doing so blurs sample and item factors, which may problematic for model fit (Wright, 1996). Secondly, in Exploratory Factor Analysis (EFA) there is no truly objective way to decide when to stop extracting factors, and the methodology for this often varies (Wright, 1996), which makes comparison of studies evaluating the structural validity of FMS assessment tools difficult. Finally, when the same set of items (i.e. the activities within an assessment tool) are re-tested on a different sample, the factor sizes and loadings are very rarely reproduced (Wright, 1996). This is likely due to CTT analyses being reliant on observed test scores, and thus the results can only be interpreted for the tested sample under the tested conditions (Hambleton, 2000; Hambleton & Van der Linden, 1982). Given the well documented “Replication Crisis” within psychological research (Maxwell et al., 2015), it is more important than ever to utilise more advanced analyses that can better account for differences across samples. More generally, there are also a number issues with using CTT methods to evaluate structural validity. One problem is that ability scores as measured CTT techniques are solely test dependent, meaning scores may not be stable over time (Magno, 2009). Moreover, every activity within a test is thought to have its own true score, even when it is known that they measure the same or closely related sub-constructs (Hambleton & Van der Linden, 1982), such as all items within an assessment battery contributing to the overarching construct of FMS.

In contrast, Item Response Theory (IRT) models are thought to enable stronger assumptions than CTT (Magno, 2009). IRT approaches do not presume a ‘true score’ but rather take into account the probability that a child may or may not be able to perform a skill, such as throwing to a target. Unlike CTT models, performance on an assessment tool is not presumed to be a ‘true reflection’ of abilities, rather IRT recognises that performance is *related* to an individual's abilities (Anastasi & Urbina, 1997), and thus total test scores are an estimate of ability, relative to the difficulty level of the activities (Magno, 2009). IRT is also stochastic in nature, and thus recognises that random disturbances to scores do occur when collecting data (e.g. scores varying across repeated measurements on the same individual), so they utilise probabilities instead of true scores (Hambleton & Van der Linden, 1982). Additionally, IRT approaches provide test scores based on a model, rather than the test scores dictating the model based on the observed data, as is seen in CTT analyses (Hambleton & Van der Linden, 1982).

In fact, in this approach, modelling is started prior to children being tested, which makes them ideal for use when developing an assessment tool from the ground up. IRT models provide individual characteristic curves for each activity within an assessment which outlines the probability of a child being able to perform a skill (Kaplan & Saccuzzo, 1997). As the emphasis is on individual activities, and reliability and error measurements are embedded within these, it provides a strong rationale for choosing certain items over others when trialling and constructing a new measurement tool (Magno, 2009). Additionally, invariance of activity parameters means that the results are not reliant on the sample, so an assessment can be developed that will be applicable across groups, in a range of settings (Magno, 2009).

One form of IRT which is growing in popularity for developing assessment tools is Rasch analysis. Rasch analysis was specifically developed to improve the level of precision when developing new assessments, as well as the monitoring of the quality of pre-existing measurement instruments (Boone, 2016). The Rasch model is often described using the vertical line (see Figure 13), in which the line represents the construct the assessment is trying to measure (e.g. FMS). Children's ability levels are represented to the left hand side of the line. On the right hand side of the line there are three activities plotted, in positions relative to their level of difficulty, with the harder activities being higher up the line (such as activity 3). Rasch analysis works on the premise that the probability of a child being able to perform an activity is a logistic function of both the child's ability level and the difficulty of the activity (Magno, 2009). For an activity that is higher up on the line than the child's ability level, there is thus a lower probability of them being able to complete it. For example, in Figure 13, Joe's ability level is equivalent to the difficulty level of item two. This means that he has a fifty percent chance of being able to complete this activity, a higher probability of completing activity one and a lower probability of completing activity three. This shared continuum is known as the logit scale (Duncan et al., 2003). Rasch analysis uses the logit scale to assess the psychometric characteristics of assessment tools (Wright & Panchapakesan, 1969).

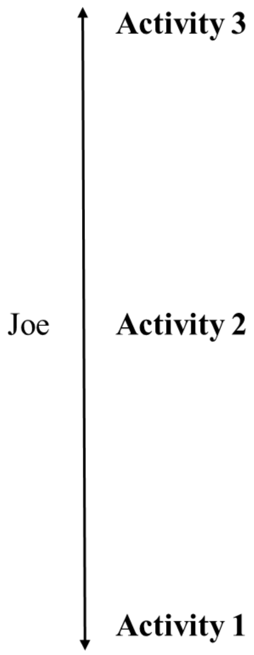


Figure 13 – Diagrammatic representation of the logit scale

Rasch analysis is recommended for use when developing a tool from scratch as it ensures that the activities fit within model parameters (Tennant & Conaghan, 2007). It also avoids the pitfalls of CTT analyses by utilising both raw scores and rating scale data to calculate ability levels (Boone, 2016). This enables abilities to be placed on a linear scale, which accounts for the differences in difficulty levels of activities. Rasch analysis is both a mathematical model (Rasch, 1960) and theory, and this theory can be applied to help guide assessment tool development. One of the advantages of using it is that researchers are required to think in depth about the concept being measured prior to developing the tool. In essence, it allows you to create a ruler (i.e. the vertical line in Figure 13), marked by the activities that will compare the FMS levels of children. To make 'marks' on the ruler, activities have to be developed, but only a limited number of marks can be made. Thus, assessment development within this theoretical framework requires forethought from researchers to ensure that activities reflect both (i) a range of ability levels and (ii) the construct intended e.g. all three sub-components of FMS. The aim, for optimal measurement is an equal distribution of activities across the length of the ruler (Boone, 2016). As Rasch theory utilises ordinal data, researchers developing assessments need to explicitly predict where on the ruler the levels of each activity will fall, to ensure they are representative of varying degrees of abilities, and that the ordering of levels is hierarchical. Once the tool is developed Rasch analysis can then be used to test these assumptions.

More precisely, once the assessment tool has been piloted, Rasch analysis allows the evaluation the difficulty levels of activities to see whether they appear in the anticipated order. Additionally it also evaluates test invariance, a term that refers to whether the difficulty level of an activity remains constant for all children taking the assessment, as well as whether bias is present within an activity for certain subgroups (Tennant & Conaghan, 2007). One example of this could be that boys found an activity easier than girls. These two factors (anticipated order and test invariance) contribute to whether activities within an assessment tool fit the Rasch model (Boone et al., 2014). There are many reasons why items may not fit the Rasch model (Wright, 1991). For example, there may have been an easy activity which high performing children performed poorly on, unexpectedly, perhaps due to lack of engagement (Boone, 2016). Activities that don't fit the Rasch model are likely measuring more than one variable, thus suggesting that the concept under investigation (e.g. FMS) is being poorly measured by the assessment. These activities can be subsequently removed or modified, after having re-visited the underlying theory to try and find an explanation and solution for their poor fit (Boone, 2016). Rasch analysis also determines whether an assessment tool's psychometric properties permit the summing of raw scores to provide a total outcome score (Rasch, 1960), something which is often done without a sound psychometric basis when using CTT models. All of these considerations combined mean that Rasch analysis is particularly useful when developing an assessment tool from the ground up.

This chapter therefore aimed to develop a school-based screening tool that is:

(i) built based on strong theoretical (based on findings from Chapter 2) and psychometric underpinnings (using Rasch analysis).
(ii) feasible for use in school settings by teaching staff (based on the feasibility guidelines outlined in Chapter 3).

4.2 Study 1

4.2.1 Initial Development of FUNMOVES

4.2.1.1 Establishing a Working Group

In order to develop a new assessment tool, an academic working group was established. The working group (including Professor Mark Mon-Williams, Dr Liam Hill, Dr Daniel Bingham, Dr Nick Preston and Jo Atkinson) was carefully convened for their expertise. The group included two psychologists that specialise in motor development. Moreover, they have relevant experience in developing a motor skill assessment tool for children that is used widely for major international programmes of work (e.g. the evaluation of London's Ultra Low Emission Zone) (Culmer et al., 2009). One of the group sits on a number of government groups (including within the UK's Department for Education) in order to provide advice on motor skill development in children.

Similarly, the team includes a physiotherapist and an occupational therapist, who have extensive experience of physically assessing children's motor ability as well as a wide range of research experience. This experience includes designing new assessment tools for motor function (Preston et al., 2018), and designing and implementing motor skill interventions in a school setting, including both handwriting (Shire et al., 2021) and FMS. There is also a behavioural epidemiologist on the team whose expertise is physical activity, but also has experience of using behaviour change theories to (i) evaluate interventions (ii) understand barriers and facilitators to new initiatives. All academics in the working group also have extensive experience working in schools, and with educational bodies, such as the Department for Education, which brings knowledge and understanding of: (i) what schools want; (ii) what would be feasible for schools; and (iii) how initiatives can be best implemented in these settings.

The working group reviewed and discussed the findings from Chapters 2 and 3, and used their expertise to contribute to decisions going forwards.

4.2.1.2 Reviewing constructs to be included

All activities developed for FUNMOVES were based on activities included in previous FMS assessments (identified by the systematic review in chapter 2) in conjunction with expert opinion (e.g. to address gaps identified). This ensured content validity and that they were in accordance with the feasibility guidelines from Chapter 3. FUNMOVES was therefore designed to measure the outcome of movements (i.e. product-oriented) using minimal resources that are commonly found in schools, within a small space (<5 metres squared).

To ensure that a whole class could be tested in under an hour, the working group decided that multiple children would have to be able to be tested on the activities simultaneously, by two members of teaching staff who have had a short training session prior to testing. Finally, it was decided that for all activities, the first 'level' should be achievable by all children, so that the self-efficacy and motivation of children with poorer motoric abilities was not challenged from the outset, to promote sustained engagement.

Chapter 2 established the three most commonly measured aspects of each sub-group of FMS within current assessment tools were: running, jumping, and hopping (locomotion skills); throwing, kicking, and catching (object control skills); as well as static balance, walking heel-to-toe and walking along a beam (stability skills). The working group decided this would be the initial pool of activities to discuss including, as it was large enough to be comprehensive but not too large that the assessment would take too long due to time constraints in schools.

There were a number of assessment tools highlighted in the systematic review that evaluate product-oriented outcomes for running including the BOT (Bruininks, 1978; Bruininks & Bruininks, 2005), FMS Polygon (Žuvela et al., 2011), and the Stay in Step Screening Test (Department of Education Western Australia, 2013), all of which utilised a timed shuttle run. The working group wanted to ensure that the running activity was not solely reliant on speed and/or other biological factors. Firstly, it was decided that this activity should be completed over a short timeframe (15 seconds) so that fitness does not have too much of an impact upon children’s performance. Secondly, emphasising agility within this task would also increase the feasibility of the running activity for school-use as it requires less space than a straight-line sprint. It was therefore decided that children should be evaluated on their agility (ability to speed up, slow down and change direction whilst maintaining balance), which is noted as a key aspect of the primary school P.E. curriculum (Department For Education, 2013).

For both jumping and hopping, activities were measured in similar ways by pre-existing product-oriented measures. Some assessments used the time taken to complete an obstacle course by hopping or jumping, including the AST and the FMS Polygon (Hoeboer et al., 2016; Žuvela et al., 2011). Others used distance jumped/ hopped, such as the FMS test Package (Adam et al., 1988; Kalaja et al., 2012) and the Stay in Step Screening Test (Department of Education Western Australia, 2013) or counted the number of jumps/hops completed, either with obstacles e.g. KTK (Kiphard & Schilling, 2007; Kiphard & Shilling, 1974) or without e.g. the MOT 4-6 (Zimmer & Volkamer, 1987). Finally, the MABC (Hendersen et al., 2007; Henderson et al., 1992) utilised jumping and hopping to target locations. As the focus on distance and quantity are likely to be more impacted by muscular strength than hopping to a target location, the working group decided to utilise a similar methodology to the MABC for these tasks.

For throwing and kicking, previously used activities exhibited similar themes to hopping and jumping, in which one focused on the number of throws/kicks in a given timeframe (Department of Education Western Australia, 2013), others scored children by the time taken to complete specific throwing/kicking tasks (Hoeboer et al., 2016; Zimmer & Volkamer, 1987; Žuvela et al., 2011) and the MABC (Hendersen et al., 2007; Henderson et al., 1992) evaluated the accuracy. For example, the number of beanbags that could be thrown to a target location. As distance thrown/kicked would require space larger than 5 x 5 metres (as per feasibility guidelines) the working group decided not to use this method for assessing throwing and kicking. In addition, for a child to participate in physical activity at a non-elite level, the speed at which they can throw/kick was not judged to be the most important factor. Moreover, research has suggested that propelling an object to a target may be more complex than propelling an object for distance as it requires integration of visual information (about the target) with a physiological response which matches the height, angle and speed of the object required upon release (Valle et al., 2018). For these reasons, the object manipulation tasks developed for FUNMOVES were designed to focus on accuracy, as it is likely to provide more information regarding potential problems with the sensorimotor system. Most pre-existing assessments use over-arm throwing, however, this is conducive to needing more space. Consequently, the working group decided to focus on under-arm throwing for FUNMOVES.

The working group had a long discussion about catching, as this skill was included in all assessment tools found to measure FMS in the systematic review (see Chapter 2). This was measured in a similar way to throwing and kicking for most assessment tools. However, the difficulty with catching is being able to standardise the presentation of the ball/ object the child is asked to catch. In all assessment tools, the difficulty of catch that children had to make was highly dependent on either their peers, a researcher, or how well they could throw to a wall at an appropriate height for the rebound to be catchable. The working group discussed ways to standardise the difficulty level of catches, including the possibility of balls or beanbags being dropped from height instead of thrown. Ultimately though, all solutions that were thought of would require either a lot of equipment, or would need a larger staff to student ratio than is normally present within a standard classroom or P.E. lesson, thus making the inclusion of such an activity unfeasible in respect to the guidelines developed in Chapter 3. For these reasons, the working group decided to omit catching from FUNMOVES.

Stability skills were grossly under-represented within pre-existing assessments of FMS. Of the assessments which included these skills, many used time as the outcome, for example how long a child could hold a balance, or how far a child could walk along a beam. The KTK (Kiphard & Schilling, 2007; Kiphard &

Shilling, 1974) also utilises the number of steps a child can take along a beam. Firstly, the working group wanted to ensure that any balance tasks didn’t require additional equipment that schools might not have. For this reason, beam walking was not included in FUNMOVES. To incorporate a dynamic balance that posed similar functional challenges to the child, the working group decided to include walking heel to toe along a line. This activity is used within the MABC (Hendersen et al., 2007; Henderson et al., 1992), and was included in FUNMOVES because such lines could be drawn using chalk, a commonly found resource in schools, as seen in Chapter 3. Alternatively, pre-existing lines in school halls could be utilised. The working group also wanted to include a form of static balance, however they did not believe that time was an appropriate outcome measure to use to assess this skill for a number of reasons. Firstly, if the outcome was the time a child could hold a balance for, it was possible that the task could take a long time. Secondly, if time cut-offs were applied, it was thought that this would be too arbitrary, with limited research on developmental norms for different balance poses. The definition of static balance was discussed, and the working group agreed on ‘the ability to maintain control of the centre of gravity in relation to the base of support’ (Shumway-Cook & Woollacott, 2007). It was therefore decided that static balance activities should require participants to shift their centre of gravity whilst maintaining a balanced position. Consequently, a novel static balance activity was developed that fitted with the feasibility guidelines outlined in Chapter 3.

4.2.1.3 The Grid

To ensure that a whole class could be tested within an hour, the working group decided that multiple children should be able to be tested on the activities simultaneously. A number of assessment formats were therefore trialled by the research team, before a five metre squared grid marked out into 25 x 1 metre squares was found to be the most promising option for conducting FUNMOVES activities (see Figure 14). This grid allows a class of 30 children to be split into five ‘teams’ (6 children per team, with one team per five metre ‘lane’). Using the grid, five children (one from each team) can then be tested simultaneously on each of the activities in turn.

All activities were designed to be implemented within this five metre squared grid (see Figure 14), to fit within space guidelines for schools (Klingberg et al., 2018), and enable the testing of five children simultaneously (one per vertical ‘lane’).

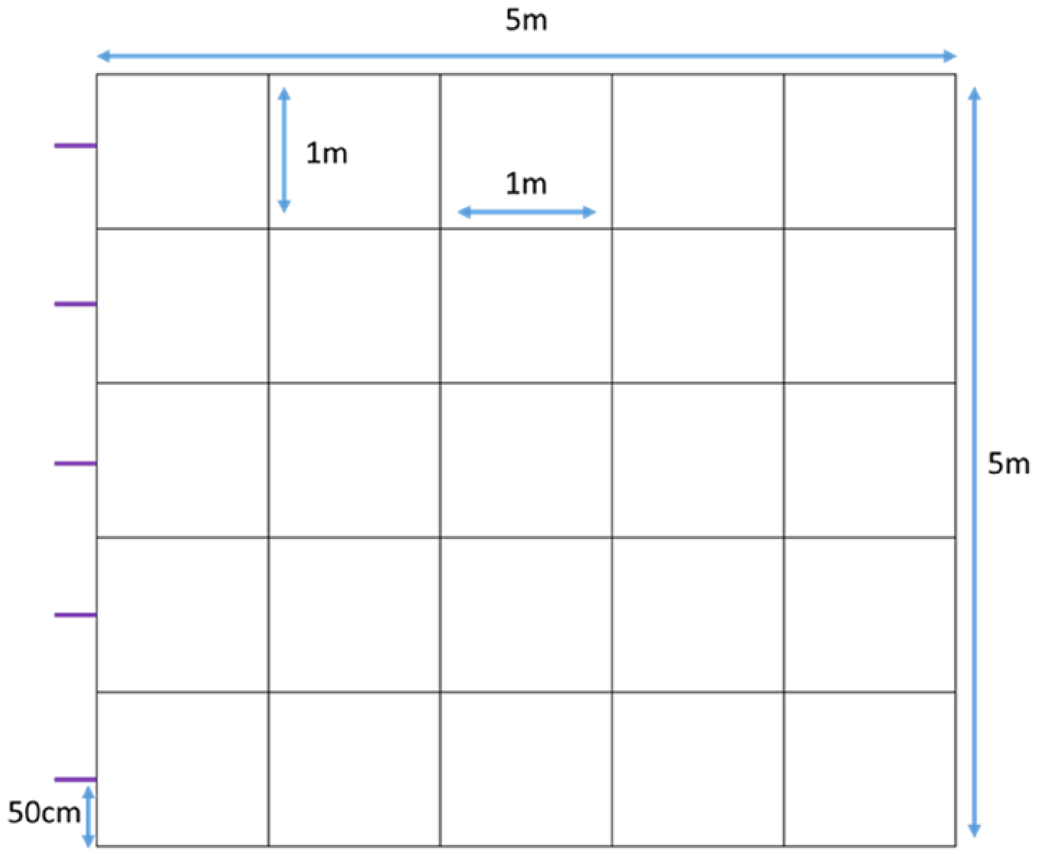


Figure 14 - Diagrammatic depiction of the grid used for FUNMOVES activities, including dimensions

4.2.1.4 Running

Children had fifteen seconds to run from the first line on the grid, to the last line on the grid, and back, as quickly as possible, repeatedly within the time limit (see Figure 15). Both lines must be touched by a foot before turning. When the teacher shouts ‘STOP’, children were required to sit down facing the way they were running. The teacher scored this activity by the number of ‘full lengths’ each child has run (from one side of the grid to the other), and the box they are sat in (written on the floor on the side of the grid). These scores allowed running to be converted to the number of metres run, which was used for analysis. In the case that a child was sat on a line between two boxes, they were marked as being in the box before (based on their direction of travel).

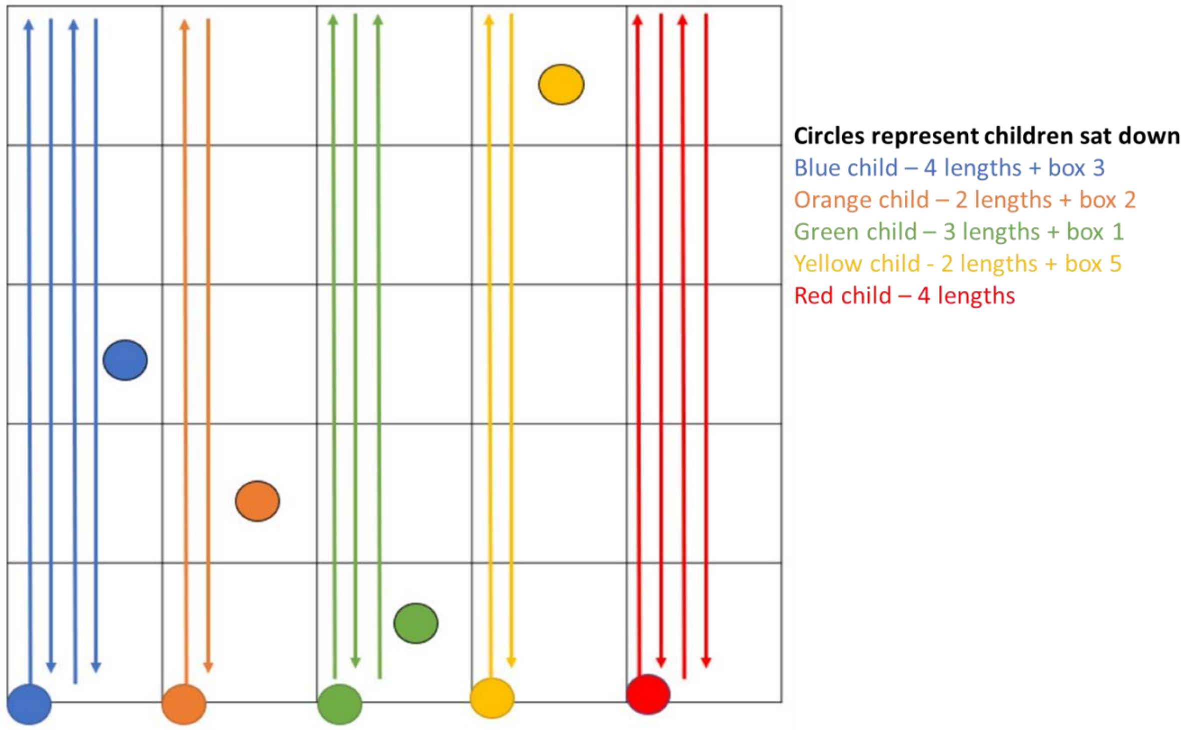


Figure 15 - Diagrammatic depiction of the running activity in FUNMOVES version 1

4.2.1.5 Jumping

When the teacher says 'GO' children jump with their feet together (as many times as necessary) from the bottom of the grid to reach the next horizontal line. Children should try to land with both feet together on the line, stop and balance. Once all children reach the line, the teacher counted to three out loud, and then set the group off jumping to the next line, where the process was repeated all the way to the far side of the grid (see Figure 16). Jumping was scored by the box where each child could no longer complete the activity as requested, for example, falling, not keeping their feet together and/or pausing not on the line. In the case of a child losing balance whilst pausing on the line, the teachers scored them as completing the activity up to the box prior to the line upon which they lost balance. Children that completed the activity and managed to balance on the back line received a score of 6.

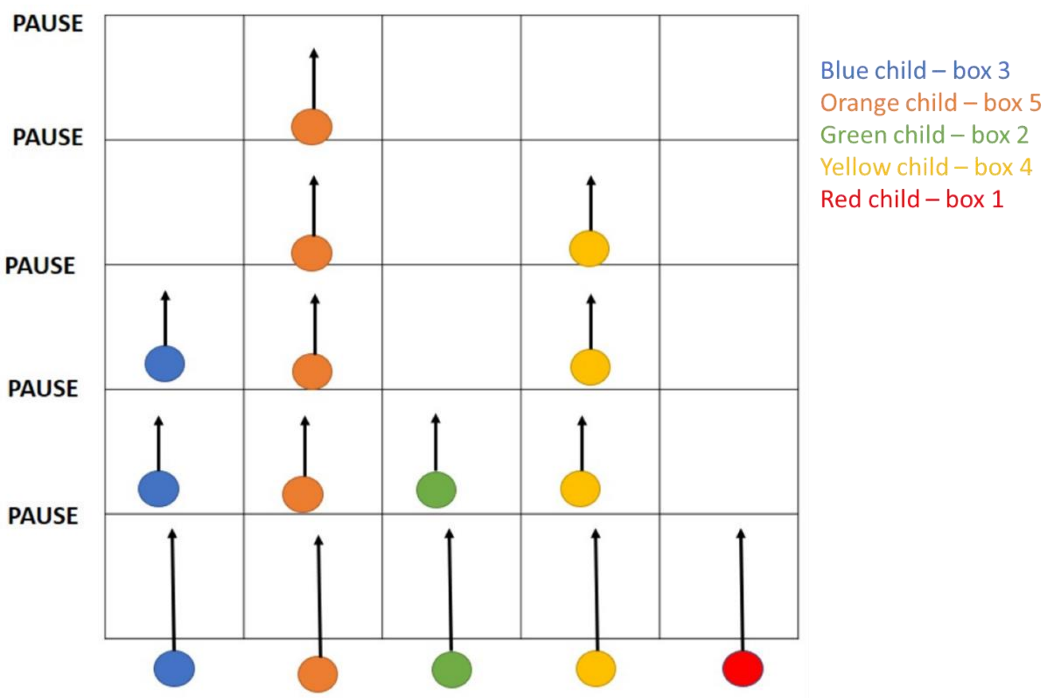


Figure 16 - Diagrammatic depiction of the jumping activity in FUNMOVES version 1

4.2.1.6 Hopping

Hopping was performed in the same way as the jumping activity. Children completed this activity twice, hopping once on their left, then once on their right leg. The criteria for scoring children was similar to the jumping task, except the “disqualification criteria” of jumping without their feet together was replaced by children putting their raised foot down whilst hopping or balancing on the line.

4.2.1.7 Throwing

Children threw five beanbags (underarm), one at a time, aiming to get one beanbag in each box within their lane (see Figure 17). Children completed this activity twice, once with their left arm and once with their right. Throwing was scored by the number of boxes in each child’s lane in which they had managed to land at least one of their beanbags. Beanbags which touched a boundary line, but did not cross it were counted towards the child’s score (see Figure 18).

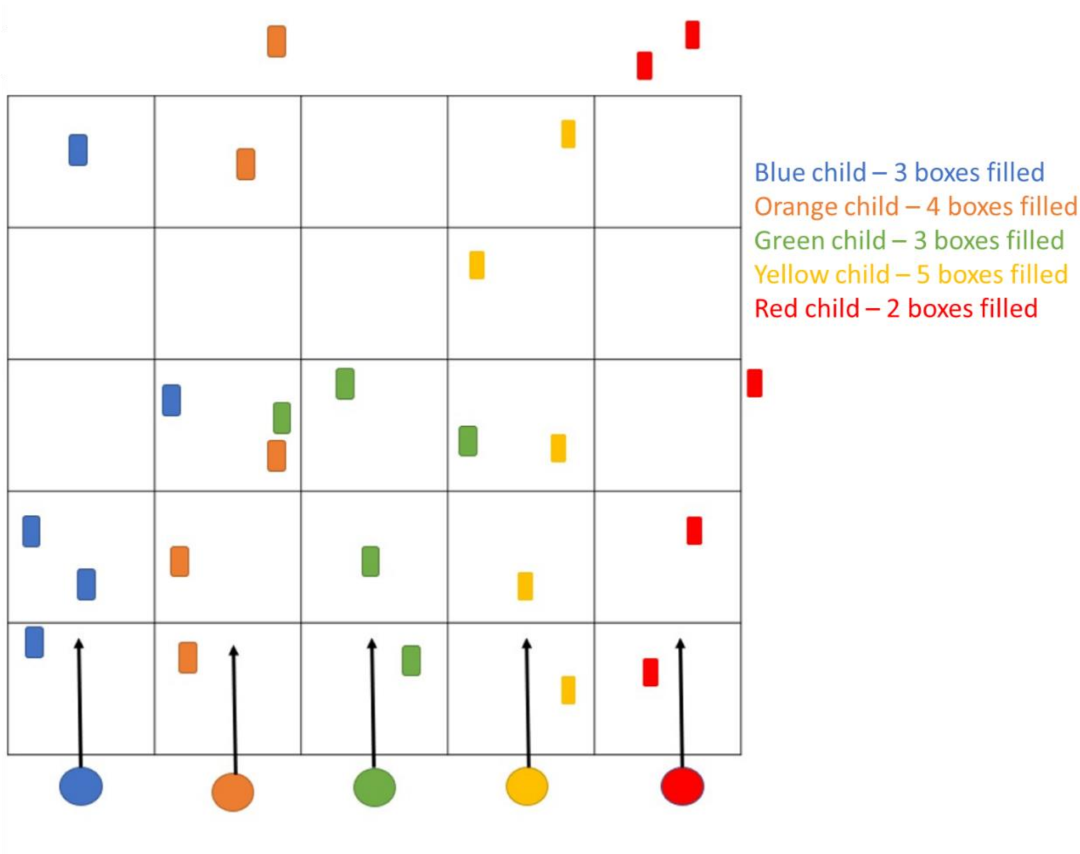


Figure 17 - Diagrammatic depiction of the throwing activity in FUNMOVES version 1

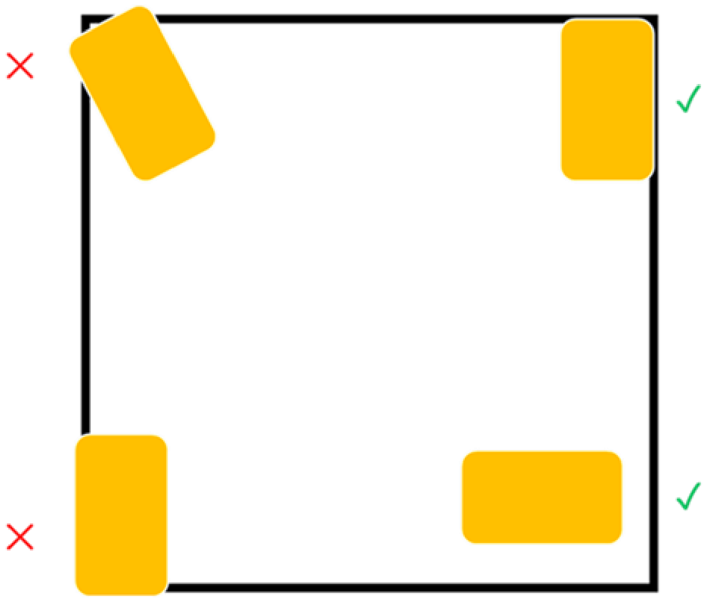


Figure 18 - a diagram explaining the rules of scoring for throwing task. The top right beanbag is counted as it is touching but not crossing the line. The two beanbags on the left are crossing the outside edge so would not be counted.

4.2.1.8 Kicking

The kicking activity was performed and scored in the same way as the throwing activity, except children kicked the beanbags along the floor on two occasions, once using their left and the other using their right foot.

4.2.1.9 Balance

Children were asked to pass a beanbag around their body, three times, whilst holding five different balance positions (see Figure 19). The balance positions assessed were: standing with feet shoulder width apart, standing with feet together, standing on one leg (right), standing on one leg (left) and standing on one leg (of their preference) with eyes closed. Children were assessed as to whether they held each balance position (yes/no) for three full rotations of the beanbag without dropping it. They were also “disqualified” on the fifth balance position if they opened their eyes during this balance.

Figure 19 - a demonstration of passing a beanbag around the body in balance position three

4.2.1.10 Walking along the line

Children walked heel-to-toe along the left hand edge of the grid, which had half metre markings made along it (see Figure 20). The activity was scored by the zone (1-10, marked on the floor with the grid) where children could no longer complete the activity as requested, this included stepping off the line and walking with a gap between their feet when walking. Children that completed the activity without any such errors were awarded a score of 11. One child at a time was assessed for this activity.

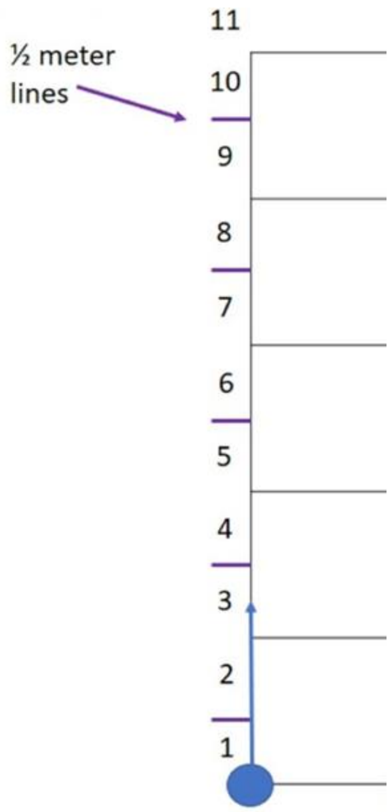


Figure 20 - Diagrammatic depiction of the walking along the line activity in FUNMOVES version 1

4.2.2 Methods

4.2.2.1 Participants

Sample size estimates were calculated in alignment with guidelines for Rasch measurement (Linacre, 1994). In order to have 99% confidence that items are calibrated within 0.5 logits, a minimum of 150 participants needed to be recruited. Three hundred and thirty one children (181 male, 150 female) from Reception to Year 6 from one Bradford primary school subsequently participated (*m* age =8.33 years, *SD*= 2 years). One class teacher responsible for the testing of a Year 1 class lost their data, so this could not be included in the analysis. Opt-out parental consent was gained prior to testing, and all children assented on the day. Before testing, teachers were asked to identify any children that they believed had motor difficulties. Across the seven year groups, teachers identified twenty-three pupils. This study, and the subsequent studies in this chapter were granted ethical approval by the University of Leeds School of Psychology Research Ethics Committee (reference number: PSC-591).

4.2.2.2 Design

This study was observational in nature, whereby data was collected on participant performance on FUNMOVES. Additionally, researchers collected data on how accurately teachers implemented each of the activities to assess implementation fidelity.

4.2.2.3 Materials

Teaching staff were given a manual (see Appendix E for the version used in Study 3), in which there was a description of how to run and score each activity. Additionally, the manual also detailed the importance of FMS for childhood development. Inclusion of this material was suggested as a solution to barriers to teacher-led FMS assessment that may exist within schools (see Chapter 3). Teachers were also provided with response sheets to fill in for their class during testing (see Appendix F for the version used in study 3). The equipment used to deliver the first iteration of FUNMOVES were: electrical tape, a stop watch, and 75 beanbags (25 per grid, as the school decided to test multiple classes simultaneously). A fidelity checklist was used to evaluate how well teachers were implementing FUNMOVES (see Appendix G). The fidelity checklist required researchers to observe teachers implementing FUNMOVES and make a judgement on how often each teacher correctly explained, demonstrated and scored each activity- ‘never’, ‘sometimes’ or ‘always’. Judgements were made based on the rules stipulated in the Teacher Manual. The checklist also had space for qualitative observations, in which researchers could note any issues observed with specific activities, and anything that teachers did particularly well.

4.2.2.4 Procedure

All teachers and teaching assistants that were going to be involved with testing attended an hour long training workshop before testing commenced. During this workshop, researchers gave a brief overview on why measuring FMS is important and the role schools can play in this. Teachers then role-played framing and scoring each activity in an interactive session. Teachers were told that children would not be permitted to practice any of the activities. Researchers encouraged teaching staff to ask questions throughout, and provided them with contact details so that any queries could be answered prior to testing. At the end of training, class teachers were given response sheets and advised to group their class in fives by perceived ability prior to starting the assessment, as well as filling out the demographic information for these groups on the response sheet prior to testing (see Figure 21 for an example of the response sheet). Demographic information was requested for use in later analyses.

Testing was completed over three days, in which three grids were set up across the two sports halls so that three classes could be tested at once. Each grid required at least one teaching assistant to be present to help the class teacher to score the activities and manage the participating pupils. For each class, children were lined up in groups of five (pre-determined by the class teacher based on ability), with their lane on the grid corresponding to their relative position on the class teachers' score sheet. Prior to children participating in each activity, teachers verbally explained and physically demonstrated the activity. All participants completed one activity before the next was explained, demonstrated, and tested. Researchers observed the testing of all classes, and an implementation fidelity checklist was filled out for each class. The school were debriefed after testing, in the form of an individual report for each child which detailed how they performed compared to the rest of their year group on each activity, calculated using percentile rank.

	Name 1	Name 2	Name 3	Name 4	Name 5
Demographics					
Gender					
Date of Birth					
Dominant Hand					
Dominant Foot					
Do you think this child has motor problems?	Y/ N	Y/ N	Y/ N	Y/ N	Y/ N

Figure 21 - an excerpt from the response sheet detailing the demographic information to be completed for each child prior to testing

4.2.2.5 Analysis

Rasch analysis was used to measure the structural validity of FUNMOVES. The analyses in this study were run using the unrestricted partial credit model in RUMM 2030 software, because responses varied between items (Masters, 1982). The analyses generate summary statistics including mean person and item locations, and a chi squared test indicating fit to the Rasch model. A perfect fit to the Rasch model would mean residual values for items and persons (z-standardised) of 0, with a standard deviation of 1; positive mean residuals would indicate that items were under-discriminating between abilities. Inversely, negative values would indicate the assessment tool may be over-discriminating (Hammond et al., 2018). A non-significant chi-square value would indicate no difference between scores expected by the model and those observed in testing, and would suggest that items were measuring consistently across different ability levels. For example, a person at 4/6 on the logit scale should have been able to successfully complete the easiest three ‘levels’ of an activity, with a 50% chance of being successful on the fourth most difficult level, and their ability should have been consistent across activities (Andrich, 1985). Internal consistency values are also calculated using the Person Separation Index (PSI). An assessment tool which has the ability to differentiate between two or more groups of ability should have a PSI value of ≥0.7 (Fisher, 1992).

Unidimensionality refers to extent to which all of the items within an assessment measure one over-arching construct, i.e. FMS. Unidimensionality was assessed using principle component analysis which identified the two most divergent subsets of items within the first factor (Tennant & Conaghan, 2007). Person estimates for each of the two sets of items were calculated, and differences between these estimates were assessed using t-tests. For a measure to be classified as unidimensional, no more than 5% of all tests should be significant, or the lower bound of the binomial confidence interval should be less than 5% (Andrich, 1985).

Analyses for individual items included fit to the Rasch model (measured using chi-squared and fit residuals), response category thresholds, item response bias (Differential Item Functioning- DIF), and response dependency. Item fit explores the extent to which each of the items fit within the expectations of the Rasch model. This analysis used ANOVAs to evaluate whether there was a statistically significant difference between class intervals. Items which do not deviate from Rasch model expectations should be non-significant (when using using Bonferroni adjustment), thus achieving the criteria required for an outcome to measure ability on a linear (interval) scale (Newby et al., 2009). Fit residuals of ≤ -2.5 would indicate an item is over-discriminating, and may be redundant, and conversely a fit residual of ≥2.5 would suggest an item is under-discriminating and measuring a different construct.

Response dependency refers to a form of misfitting in the Rasch model whereby a person's score on one item has a bearing upon their performance on another item, which introduces redundancy to the scale. Dependency can have an impact upon the relationship between all items as well as unidimensionality (Marais & Andrich, 2008). Correlations between item residuals were used to assess local dependency. The threshold for dependency between items is the average item residual +.2 (Chen & Thissen, 1997). Response category thresholds explored the extent to which each 'level' of scoring was represented by a different level of ability within the sample. Thresholds refer to the point on the logit scale between two different scores. Participants falling at a threshold point on the logit scale should be equally likely to obtain either score. Figure 22 shows an example of ordered thresholds, in which participant ability (logit scores) follow a logically progressive order, whereby the higher a person's ability is, the more likely it is that they will obtain a better score on an activity. Disordered thresholds occur when scoring categories do not progress in a logical order.

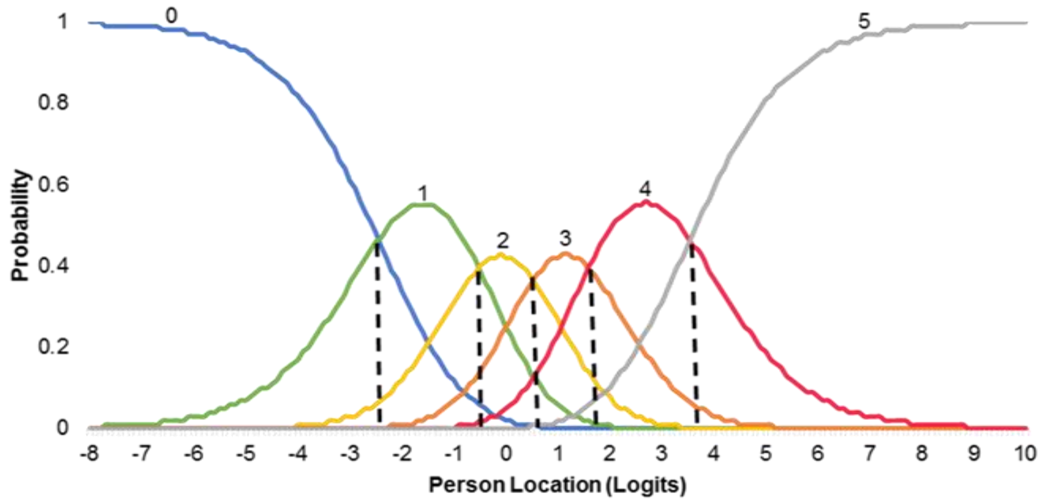


Figure 22 - a category probability curve showing an example of ordered thresholds for scoring. The dotted lines indicate the threshold between scoring categories

In Figure 22, the x axis refers to the logit scale (the shared scale for person ability and task difficulty). Zero on the logit scale indicates 'average' ability. Children who perform below average on activities within an assessment tool will be placed lower down the logit scale (i.e. into the minuses). Similarly, the easier a scoring threshold is to achieve, the further left on the logit scale it will appear.

The y axis represents the probability that a child can achieve scoring categories. On Figure 22, you can see that a child who is between -8 and -3 on the logit scale, is never more likely to score 1 than 0, and thus it is highly probable that they will score 0 on the task. Children at -2.5 on the logit scale fall at a scoring threshold (pictured on Figure 22 as a dotted black line), which means that a child is equally likely to achieve either score. Children with this ability level (-2.5 on the logit scale) will therefore have a 50% chance of achieving 0 or 1 on the activity.

DIF is another factor which can introduce mis-fitting into the model. DIF was evaluated using an ANOVA to assess whether FUNMOVES measured consistently between year groups. There are two forms of DIF (1) uniform DIF and (2) non-uniform DIF. Uniform DIF occurs when one group is consistently achieves higher scores than another. When inconsistencies in the differences between groups occur then non-uniform DIF is found.

Rasch analysis is thought to be a more accurate and comprehensive at measuring construct validity than factor analysis (Wright, 1996) and has been used previously to validate measures of motor skill (Avery et al., 2003; Bardid, Utesch, et al., 2019; Chien & Bond, 2009; Utesch et al., 2016; Wuang et al., 2009). In the case that FUNMOVES was multidimensional or had response dependency, items were removed. To ameliorate disordered thresholds, two or more adjacent categories may be combined. To evaluate the external validity of FUNMOVES, an ANOVA was conducted using mean logit scores to see whether there were significant differences between school year groups, and whether or not teachers thought each child had motor difficulties prior to testing.

4.2.3 Results

4.2.3.1 Implementation Fidelity

Table 19 provides an overview of the clarity of teacher instructions, demonstrations, and their accuracy in scoring. The most problematic items to score were static balance and walking along the line, for which teachers only scored the activity correctly 38% and 30% of the time respectively. As indicated in Table 20, for these items researcher notes suggested comprehension (both children and teacher) and ability (child only) issues with delivering these items. Additionally, for the jumping and hopping activities it was apparent that the way children were doing the activity was not standardised, and that some children were doing multiple small jumps/hops between the lines, whilst others were doing one big jump/hop from line to line (making the activity more difficult).

Table 19 – Teacher Implementation Fidelity for Study 1

Activity	Aspect of Activity	Teachers that never implemented it correctly (%)	Teachers that sometimes implemented correctly (%)	Teacher that always implemented it correctly
Running	Instructions	0	15	85
	Demonstration	0	15	85
	Scoring	0	23	77
Jumping	Instructions	0	8	92
	Demonstration	0	8	92
	Scoring	0	31	69
Hopping	Instructions	0	8	92
	Demonstration	0	8	92
	Scoring	0	23	77
Throwing	Instructions	0	15	85
	Demonstration	0	0	100
	Scoring	0	8	92
Kicking	Instructions	0	15	85
	Demonstration	0	23	77
	Scoring	0	15	85
Balance	Instructions	0	8	92
	Demonstration	0	23	77
	Scoring	0	62	38
	Instructions	0	0	100

Activity	Aspect of Activity	Teachers that never implemented it correctly (%)	Teachers that sometimes implemented correctly (%)	Teacher that always implemented it correctly
Walking along the line	Demonstration	0	0	100
	Scoring	0	70	30

Table 20 - Emerging themes from the qualitative comments section of the implementation fidelity checklist: for static balance and walking along the line

Theme	Activity	Researcher Comments
Child Comprehension	Static Balance	**Researcher A:** ‘teachers had to continually demonstrate the activity whilst each group of children were being tested – children were confused and were therefore getting practice and multiple testing opportunities’
Teacher Comprehension	Static Balance	**Researcher C:** ‘instructions for left and right need to be clearer i.e. when they say left leg, should they stand on or raise that leg?’
	Walking Along the Line	**Researcher C:** ‘they were setting children off very close together, problems for children following another child could occur if they have to pause to wait. This meant that the teacher wasn’t watching them for the full length of the course’ **Researcher A:** ‘there was a little confusion over who was watching which child, due to them setting too many children off at once, meaning some scores were not an accurate representation of their ability’ **Researcher A:** ‘children were not walking heel to toe, and there was confusion over how these children should be scored because they were still technically on the line’.
Child Ability	Static Balance	**Researcher B**: ‘teacher had to improvise with Reception as passing beanbags around the body was too difficult, so the

Theme	Activity	Researcher Comments
		class did a clap at the front and a clap at the back' **Researcher C:** 'The activity took a long time because children struggled with left and right'

4.2.3.2 Initial Rasch Analysis

The initial Rasch analysis revealed a number of issues with this initial version of FUNMOVES, including misfit to the Rasch model ($\chi^2(40)= 108.03$, $p<.001$), and internal consistency below the accepted level (PSI =.68).

Table 21 shows an overview of the summary statistics for study 1. Items displaying misfit to the Rasch model (after Bonferroni adjustment ($p<.005$) were running ($F(4,318)= 6.10$, $p<.001$), non-dominant leg hopping ($F(4,307)= 5.36$, $p<.001$) and static balance ($F(4,320)= 7.73$, $p<.001$). Five items displayed disordered thresholds – jumping, hopping (both dominant and non-dominant leg), non-dominant leg kicking and walking along the line (see Figure 23).

Figure 23b shows that children were never more likely to score 1 or 2 than 0 nor were they more likely to score 3 or 4 than 5. Thus, children below 0.2 on the logit scale were most likely to score 0 and children with higher ability levels than this were most likely to score 5. Similarly Figure 23e shows ordered thresholds apart from scoring category 4 (pink line), which never reaches a higher probability of being obtained than scores of 3 or 5. Thus, children with an FMS ability level of 2.2 on the logit scale were equally likely to score 3 or 5, making 4 a redundant response category.

There was also evidence of item response bias for running ($F(6)= 5.41$, $p<.001$), jumping ($F(6)= 6.78$, $p<.001$), static balance ($F(6)= 6.63$, $p<.001$) and walking along the line ($F(6)= 4.33$, $p<.001$) by year group, after accounting for Bonferroni adjustment ($p<.002$). Additionally, running showed item-response bias by gender ($F(6)= 12.81$, $p<.001$). No DIF was found between 'typically developing' children, and children identified by teachers prior to testing as potentially having motor issues. Correlations between item residuals also identified local dependency for two sets of items (r >.15): (i) hopping dominant and non-dominant leg ($r = .41$) and (ii) kicking dominant and non-dominant foot ($r = .19$). The assessment tool was also not unidimensional, as 32 of the 323 t-tests (9.64%) were significant. One participant response was found to be misfitting (P23, location = -.29, $SE= .65$).

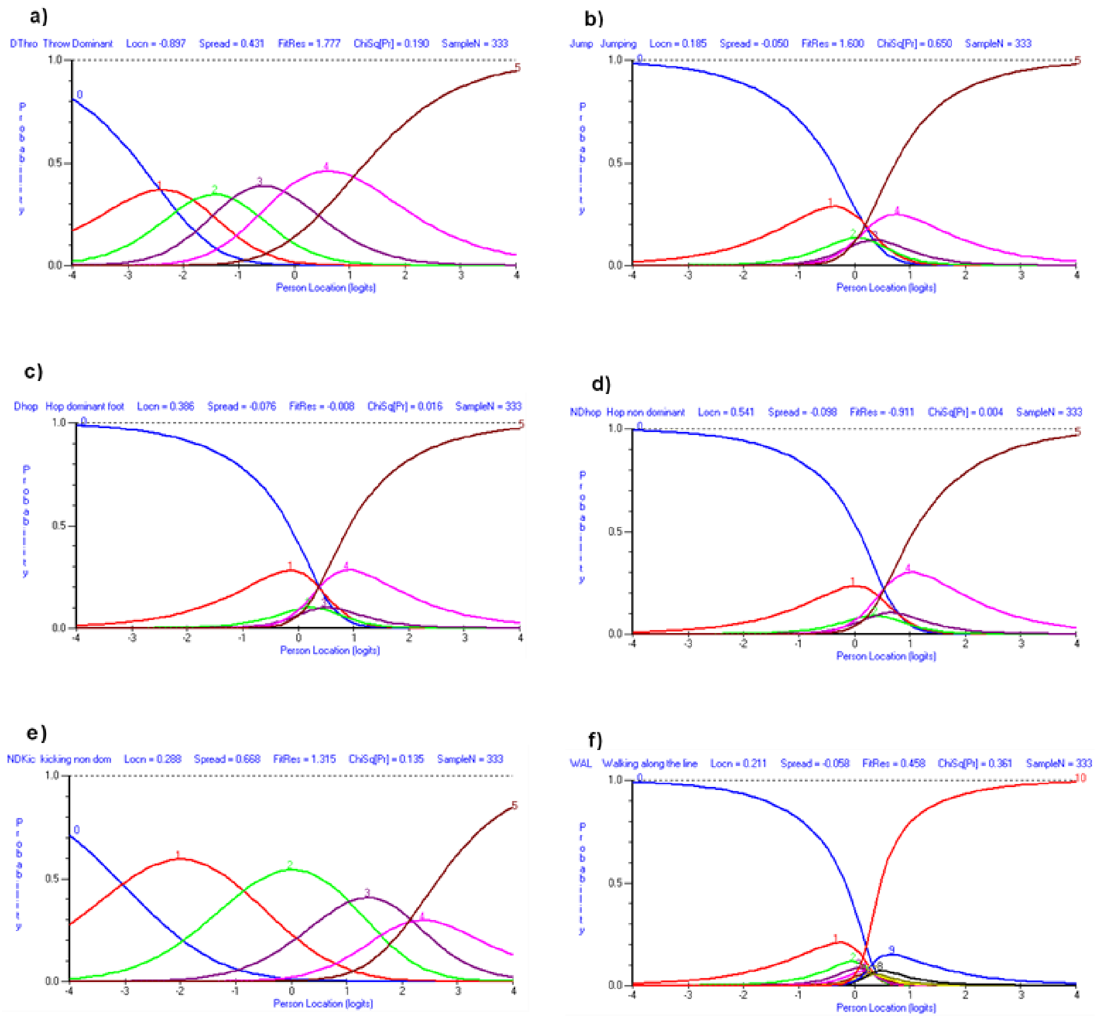


Figure 23 - category probability curves from study 1 initial Rasch analysis.

NB: a) shows an example of ordered thresholds (from the throwing activity) b) shows disordered thresholds for jumping; c) shows disordered thresholds for dominant leg hopping, d) shows disordered threshold for non-dominant leg hopping, e) shows disordered thresholds for non-dominant leg kicking and f) shows disordered thresholds for walking along the line. Graphs were generated by RUMM 2030 software.

4.2.3.3 Items removed

Non dominant leg hop, non-dominant foot kick, and walking along the line were removed and the analysis re-run in an effort to ameliorate local dependency and implementation fidelity problems noted with these tasks. This second analysis revealed that these changes resulted in no local dependency between items (limit *r* >.19) and no DIF for gender or motor problems. However, there were still a number of issues with this the subset of activities in FUNMOVES that remained in this analysis. Namely, mis-fitting to the Rasch model (χ^2(28)=

47.10, p =.01), lower than acceptable PSI (.6), and the measure being a multidimensional rather than unidimensional (7.12% of tests). Additionally, running (F(4,318)= 8.12, p<.001) and balance (F (4,320)= 4.51, p<.001) activities were misfitting after Bonferroni adjustment (p<.001). Running, jumping, hopping, and non-dominant throw all had disordered thresholds (see Figure 24), and there was uniform DIF (for year group when using Bonferroni adjustment p<.002) for running (F(6)= 3.95, p=.001), jumping (F(6)= 7.95, p<.001) and balance (F(6)= 7.35, p<.001). Finally, one misfitting person was found (P32, location = .08, *SE*= .67).

Table 21 – Summary Statistics for Study 1

	Item location		**Person location**		**Item fit residual**		**Person fit residual**		**Chi-square interaction**			**Person Separation Index (PSI)**		**Unidimensionality**			
Analysis	*m*	SD	*m*	SD	*m*	SD	*m*	SD	Value	*df*	*p*	With Extrms	No Extrms	Number of sig tests	Out of	%	Lower 95% CI
Initial	0	.51	.16	.29	.70	1.09	-.11	.96	108.3	40	<.001	.68	.69	32	323	9.64	.07
Items Removed	0	.52	.29	.30	.50	3.41	-.16	.94	47.1	28	.01	.59	.60	23	323	7.12	.05
Rescore Run	0	.54	.3	.52	.45	.90	-.19	.89	31.79	28	.28	.58	.59	9	323	2.79	.004

NB: Extrms refers to individuals with an extreme fit residual.

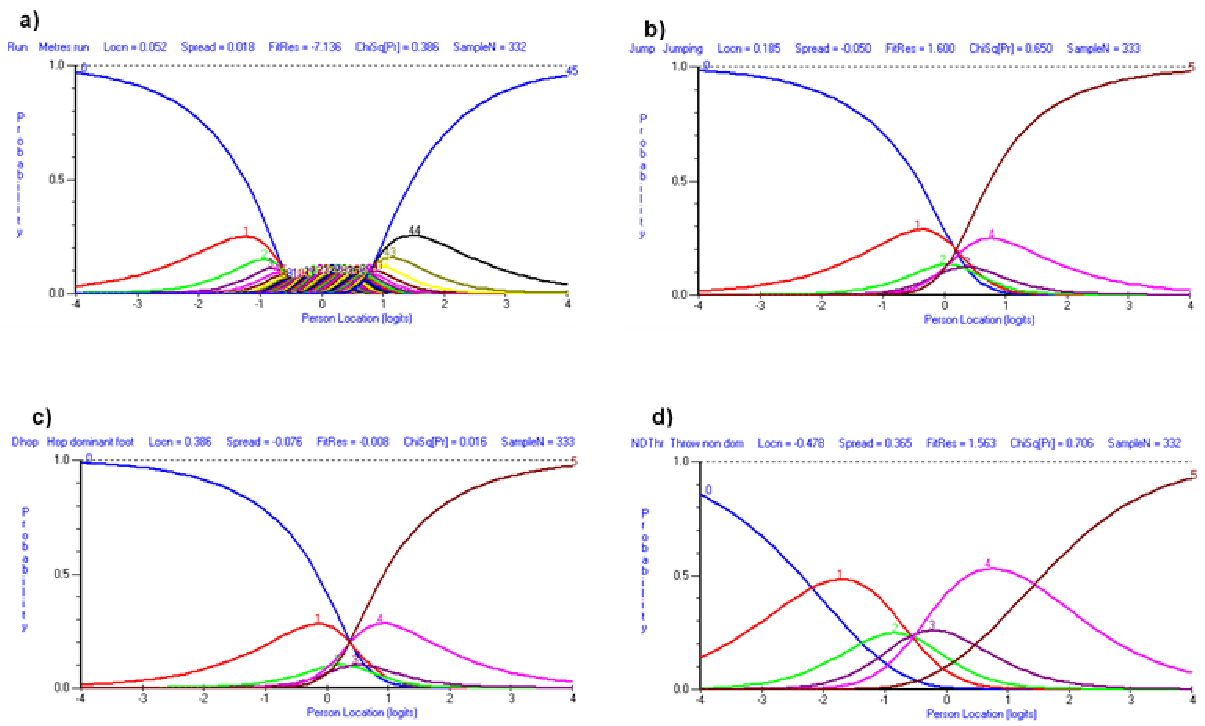


Figure 24 – category probability curves for study 1, items removed analysis

NB: a) shows disordered thresholds for running b) shows disordered thresholds for jumping; c) shows disordered thresholds for dominant leg hopping, d) shows disordered threshold for non-dominant hand throwing. Graphs were generated by RUMM 2030 software.

4.2.3.4 Rescoring the Running Activity

Due to running having disordered thresholds and misfitting the Rasch model in the second analysis, a further re-analysis was performed where this activity was re-scored, to see if this improved fit. Children were scored on the number of full lengths (5 metre runs) instead of the number of metres a child ran. This re-scoring resulted in FUNMOVES fitting the Rasch model ($\chi^2(28)= 31.79$, p =.28), with no mis-fitting items (after Bonferroni adjustment, p<.007), and achieving unidimensionality (2.37% of tests), with no local dependency (limit = r >.04) and no DIF for gender or teacher identified motor problems. Additionally, ANOVAs revealed significant differences between the scores obtained by different year groups (F(6,326)=19.05, p<.001, see Table 22), as well as between ‘typically developing’ children and children that were identified by teachers prior to testing as potentially having motor difficulties (F(1,296)=25.35, p<.001, see

Table 23). Additionally, there was no significant difference between the mean logit location of males and females ($F(1,308)=.90$ $p=.34$, see Table 24).

Table 22 – Descriptive statistics for logit location on FUNMOVES by year group for study 1

Year Group	*n*	*m*	*SD*
Reception	47	-0.07	0.46
Year 1	28	-0.05	0.42
Year 2	51	0.22	0.42
Year 3	53	0.14	0.44
Year 4	46	0.41	0.46
Year 5	50	0.73	0.56
Year 6	58	0.5	0.41

Table 23 – Descriptive statistics for logit location on FUNMOVES by motor ability for study 1

Motor Skill	*n*	*m*	*SD*
No problems	276	0.36	0.47
Teacher identified problems	22	-0.2	0.5

Table 24 – Descriptive statistics for logit location on FUNMOVES by gender for study 1

Gender	*n*	*m*	*SD*
Male	170	0.27	0.51
Female	140	0.32	0.53

A number of issues with this iteration of FUNMOVES were, however, highlighted with this third and final re-analysis. Similar to the second analysis, the PSI was lower than acceptable (.59), and one participant had an extreme fit residual (P32, location = .07, *SE*= .70). Secondly, there was uniform DIF for year group (when accounting for Bonferroni adjustment *p*<.002) for running (*F(*6)= 7.36, *p*<.001), jumping (*F*(6)= 9.19, *p*<.001) and balance (*F(*6)= 5.54, *p*<.001). Additionally, despite re-scoring the running activity, thresholds were still disordered (see Figure 25).

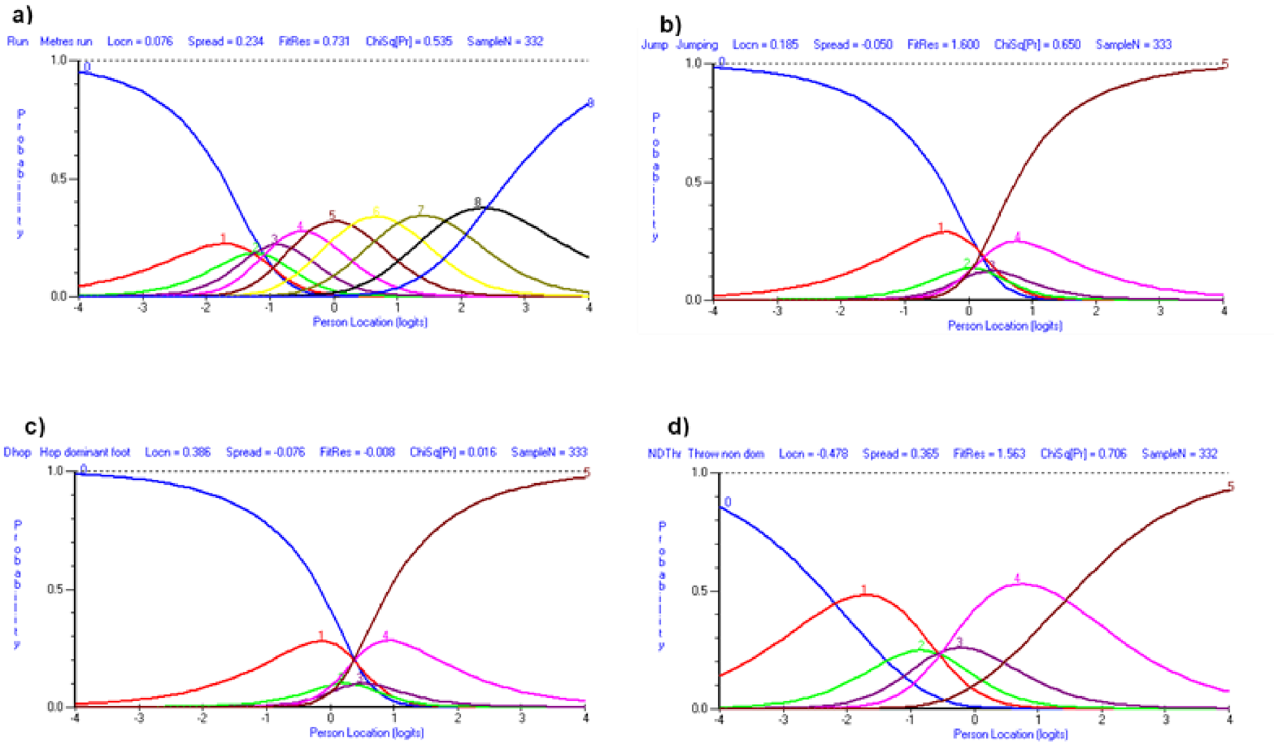


Figure 25 - category probability curves for study 1, rescore running analysis

NB: a) shows disordered thresholds for running b) shows disordered thresholds for jumping; c) shows disordered thresholds for dominant leg hopping, d) shows disordered threshold for non-dominant hand throwing. Graphs were generated by RUMM 2030 software.

4.3 Study 2

4.3.1 Methods

4.3.1.1 Participants

Three hundred and fifteen children (165 male, 150 female) in Years 1-6 from one school in Bradford participated in Study 2 (*n*=315, *m* age =8.37 years, *SD*= 1.83 years). Reception were not tested after Study 1, due to issues arising with attention and comprehension in this age group, which resulted in FUNMOVES not being feasible to implement at a whole class level in this age group (as highlighted by the teachers from Study 1). Prior to testing, class teachers identified 45 pupils that they thought had motor problems.

4.3.1.2 Design, Materials, Procedure and Analysis

The design, procedure for evaluating FUNMOVES and analysis were all the same as in Study 1. Materials remained the same, except changes were made to the teacher manual to reflect changes to activities in FUNMOVES based on the results of implementation fidelity and Rasch analysis. This included removing walking along the line and non-dominant leg kicking. Balance was modified to remove balance 1 (legs shoulder width apart) as all children could perform this balance and balance 2 (feet together), so it was redundant to include both. Additionally, the need for children to balance on both their left and right leg was removed due to confusion about which leg should be the standing leg, and so for study 2, children were allowed to choose which leg to stand on during one leg balances. This was presumed to be their dominant leg, and will be referred to hereafter as such. An extra balance was also added, as two balances had been removed (non-dominant one leg balance, and legs shoulder width apart – based on the analysis in Study 1). The new balance entailed a child standing on one leg, dropping a beanbag in front of them at arm's length and then attempting to pick the beanbag up off the floor with one hand whilst maintaining balance (see Figure 26). This activity was included as it is regularly used in occupational therapy assessments.

Figure 26 – photographic representation of the new balance included in Study 2

Additionally, the implementation fidelity checklist was modified based on advice from Professor Jackie Goodway at the International Motor Development Research Consortium conference. Rather than the frequency of correct instructions, demonstrations and scoring, the checklist was changed to reflect 'essential' criteria that teachers must meet to accurately implement FUNMOVES, and 'desirable' criteria which helps the assessment run smoothly (see Appendix H).

4.3.2 Results

4.3.2.1 Implementation Fidelity

There was full compliance with essential criteria in nine out of the twelve classes tested. There were issues with instruction-giving and scoring recorded in the remaining three classes (see Table 25). Researchers did not observe any further issues in their qualitative comments that did not relate to the checklist criteria.

Table 25 – Implementation Fidelity Issues for Study 2

Class	% Essential Criteria Met	Activity where essential criteria was not met	Criteria not met
1A	100	n/a	n/a
1B	94	Jumping	Scoring was not deemed accurate by researchers
		Balance	Did not say that feet need to be together for balance one
			Did not count out the rotations of beanbags around the body so children were completing the balances at different speeds and were thus balancing for unequal amounts of time
2A	94	Running	Didn't tell children to run as quickly as they can

Class	% Essential Criteria Met	Activity where essential criteria was not met	Criteria not met
			Didn't say that they should touch the line at both sides with their feet
			Didn't demonstrate the task properly
3A	100	n/a	n/a
3B	100	n/a	n/a
4A	100	n/a	n/a
4B	96	Running	Scoring was not deemed accurate by researchers
		Balance	Didn't demonstrate balance four
5A	100	n/a	n/a
5B	100	n/a	n/a
6A	100	n/a	n/a
6B	100	n/a	n/a

4.3.2.2 Initial Rasch Analysis

The Rasch analysis undertaken in Study 2 revealed several substantial improvements compared to the results of study 1, with the internal consistency increasing to an acceptable level (*PSI* = .71), and no DIF was found between typically developing children and teacher identified children. Additionally, there was no local dependency between items (limit *r* = .05) and none of the participant's responses were exceeded thresholds for being classified as 'extreme' and thus ill-fitting. FUNMOVES was also found to be unidimensional, with only 4.31% significant t-tests. Table 26 shows an overview of the summary statistics for study 2.

There were, however, a number of issues with FUNMOVES still highlighted by this analysis. Item-trait interaction was significant ($\chi^2(28) = 45.17$, $p = .02$), indicating some misfit to the Rasch model. Additionally, there were 3 items with disordered thresholds – jumping, hopping and balance (see Figure 27), and jumping also showed some degree of mis-fitting to the Rasch model ($F(4,320)=3.96$, $p=.004$). There was also evidence of item response bias by year group for both running ($F(5)= 6.07$ $p<.001$) and jumping ($F(5)= 5.82$, $p<.001$), as well as by gender for running ($F(1)= 17.01$, $p<.001$) and hopping ($F(1)= 13.20$, $p<.001$).

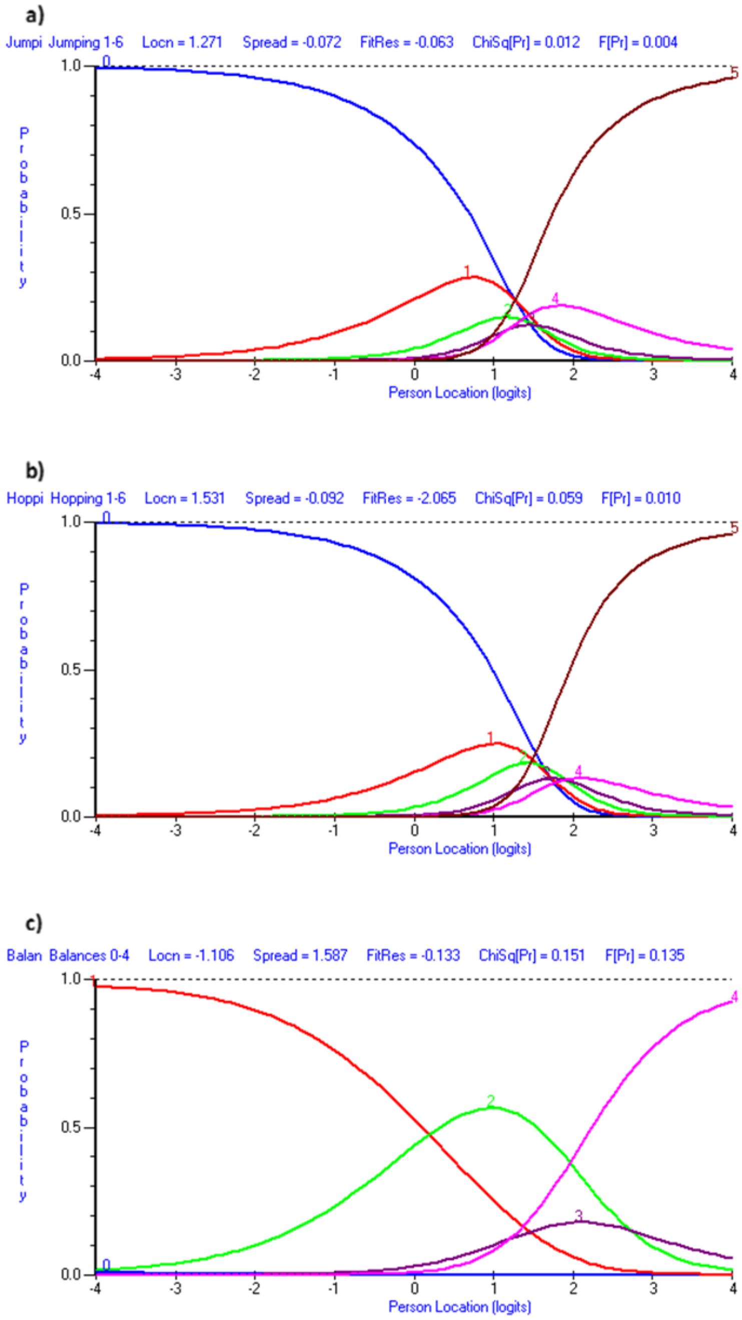


Figure 27 - category probability curves from study 2 initial analysis.

NB: a) shows disordered thresholds for jumping; b) shows disordered thresholds for hopping and c) shows disordered threshold for balance. Graphs were generated by RUMM 2030 software.

Table 26 – Summary Statistics for Study 2

	Item location		**Person location**		**Item fit residual**		**Person fit residual**		**Chi-square interaction**			**Person Separation Index (PSI)**		**Unidimensionality**			
Analysis	*m*	SD	*m*	SD	*m*	SD	*m*	SD	Value	*df*	*p*	With Extrms	No Extrms	Number of sig tests	Out of	%	Lower 95% CI
Initial	0	1.24	.98	.73	.15	1.23	-.26	.89	45.17	28	.02	.71	.71	14	325	4.31	.02
Rescore	0	1.56	1.1	.90	.24	1.14	-.22	.98	57.34	28	<.001	.68	.68	19	325	5.85	.04

NB: Extrms refers to individuals with an extreme fit residual.

4.3.2.3 Rescore Jump and Hop

Due to jumping, hopping and balance having disordered thresholds in the initial analysis (see Figure 27), these activities were re-scored for a second analysis. Scoring changes were made based on the frequency of responses within original scoring categories. Jumping and hopping were changed to have three levels, by combining scores 1 and 2, 3 and 4 as well as 5 and 6. Also, because children were never more likely to score 3 than 4 for balance, these two scoring categories were combined.

Re-scoring these problematic activities in this way did not improve fit to the Rasch model ($\chi^2(28)= 57.34$, $p<.001$), nor did it improve gender DIF for running ($F(1)=12.21$, $p<.001$) or hopping ($F(1)=15.83$, $p<.001$) when accounting for Bonferroni adjustment ($p<.002$). Additionally, non-uniform DIF was also found by year group for hopping ($F(5)=4.18$, $p=.001$) and kicking ($F(5)=4.19$, $p=.001$), in addition to maintaining this uniform DIF for running ($F(5)=4.70$, $p<.001$). Additionally, these changes reduced the internal consistency to below the accepted level (PSI = .68), and led to the hopping activity not fitting the Rasch model ($F(4,320)=7.21$, $p<.001$) when accounting for Bonferroni adjustment ($p<.001$). Re-scoring these activities, did however, result in ordered scoring thresholds. Additionally, ANOVAs showed that there was a significant difference between the scores obtained by year groups (see Table 27; $F(5,319)=56.74$, $p<.001$) and between the scores obtained between typically developing children and teacher identified children (see Table 28; $F(1,319)=7.99$, $p=.005$) on these activities. There was also no significant difference between the mean logit scores of males and females (see Table 29; $F(1,319)=.48$, $p=.49$)

Table 27 - Descriptive statistics for logit location on FUNMOVES by year group for study 2

Year Group	***n***	***m***	***SD***
Year 1	55	0.11	0.65
Year 2	49	0.58	0.75
Year 3	47	0.94	0.52
Year 4	59	1.28	0.66
Year 5	60	1.75	0.65
Year 6	55	1.82	0.71

Table 28 - Descriptive statistics for logit location on FUNMOVES by motor ability for study 2

Motor Problems	***n***	***m***	***SD***
No	275	1.14	0.92
Yes	45	0.74	0.7

Table 29 - Descriptive statistics for logit location on FUNMOVES by gender for study 2

Gender	***n***	***m***	***SD***
Male	169	1.13	0.87
Female	152	1.1	0.94

4.4 Study 3

4.4.1 Methods

4.4.1.1 Participants

Two schools in Bradford were recruited for the final round of testing, in which year 1-6 participated (*n* = 421, 196 male, *m* age = 8.61, *SD* = 2.1 years). Teachers identified eight children as having potential motor skill difficulties.

4.4.1.2 Design, Materials, Procedure and Analysis

The design, evaluation procedure and analysis were all the same as in Studies 1 and 2. Materials remained the same as in Study 2, with the exception of the following changes to the teacher manual, which reflected changes to the protocol for certain activities within FUNMOVES in response to the results of implementation fidelity and Rasch analysis in Study 2. As can be seen in Figure 27, the scoring categories for jumping and hopping were not differentiating between abilities. This demonstrates that the ‘levels’ within these activities did not get progressively more difficult. These activities were modified so that children had to jump or hop to a target zone (marked out in a different colour) on each line. The target zones became progressively smaller, in which the whole of the first line (1 metre wide) was the target zone, up to the final line where this narrowed to a 10 cm target zone for children to land on (see Figure 28). Additionally, Figure 27 demonstrates that children were never more likely to be able to complete Balance 3 than Balance 4. This showed that the final two balances were in the wrong order for their difficulty level, and were therefore swapped over for study 3 (i.e. Picking up a beanbag became Balance 3 and was completed prior to Balancing with eyes closed, which was labelled Balance 4).

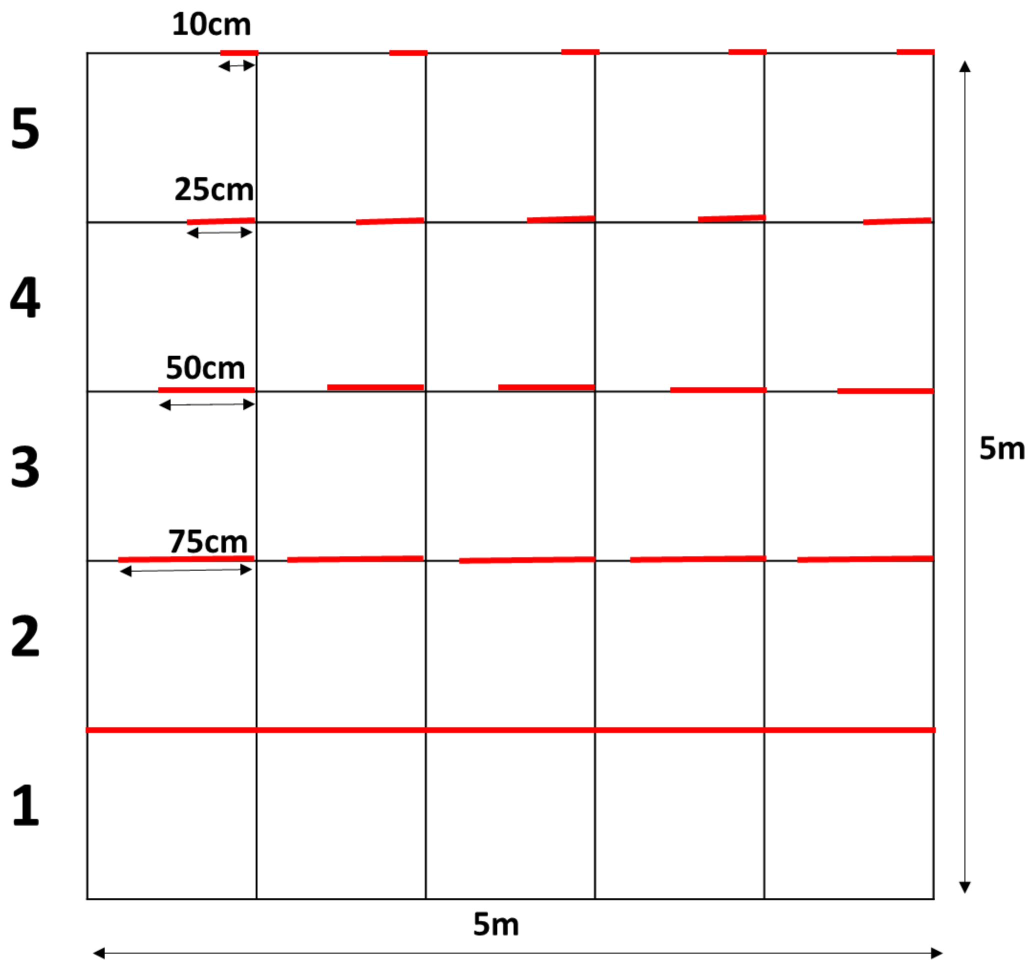


Figure 28 – Illustration of the target zones on each line of the grid which were used to score jumping and hopping in study 3

4.4.2 Results

4.4.2.1 Implementation Fidelity

The implementation fidelity data from one of these schools was incomplete and not meaningful, due to a lack of engagement in teacher training, and little time being allocated for testing. This led to researchers having to take over sessions or come back to lead and score some of the activities. For the second school tested in, there was full compliance with essential criteria in four out of the six year groups participating, and there were only issues with instruction-giving recorded in the remaining two (see Table 30). Researchers deemed the timing and scoring of activities as reliable for all year groups.

Table 30 - Implementation Fidelity Issues for Study 3 (one school)

Year Group Assessed	% Essential Criteria Met	Activity where essential criteria was not met	Criteria not met
1	85	Running	Teacher did not demonstrate (asked researcher to)
		Jumping	Not explaining that they need to pause on the final line too
		Hopping	Not explaining that they need to pause on the final line too Teacher did not demonstrate (asked researcher to)
		Balance	Teacher did not demonstrate (asked researcher to)
2	100	n/a	n/a
3	92	Set up	Teacher did not line up students in teams Children were not lined up in the order on their response sheets
		Hopping	Did not tell students that they couldn't change legs during activity
4	100	n/a	n/a
5	100	n/a	n/a
6	100	n/a	n/a

4.4.2.2 Both Schools - Initial Rasch Analysis

The Rasch analysis showed further improvement upon the results reported in Study 2, in that FUNMOVES fit the Rasch model ($\chi^2(42)= 55.39$, p =.08). It was also unidimensional (5.94% of tests, *CI* = .04, .08), there was no local dependency between items (limit r = .05) and no misfitting people or items when accounting for Bonferroni adjustment (p<.007) . Summary statistics for all analyses from study 3 can be seen in Table 31.There were, however, a number of issues identified in this analysis. Firstly, the internal consistency of FUNMOVES was lower than acceptable (PSI = .64). Running, jumping and hopping had disordered thresholds (see Figure 29). Additionally, uniform DIF was found for year group for hopping ($F(5)=3.82$, $p=.002$) and balance ($F(5)=5.92$, $p<.001$), as well as for gender for running ($F(1)=25.47$, $p<.001$), kicking ($F(1)=13.38$, $p<.001$) and balance ($F(1)=12.97$, $p<.001$).

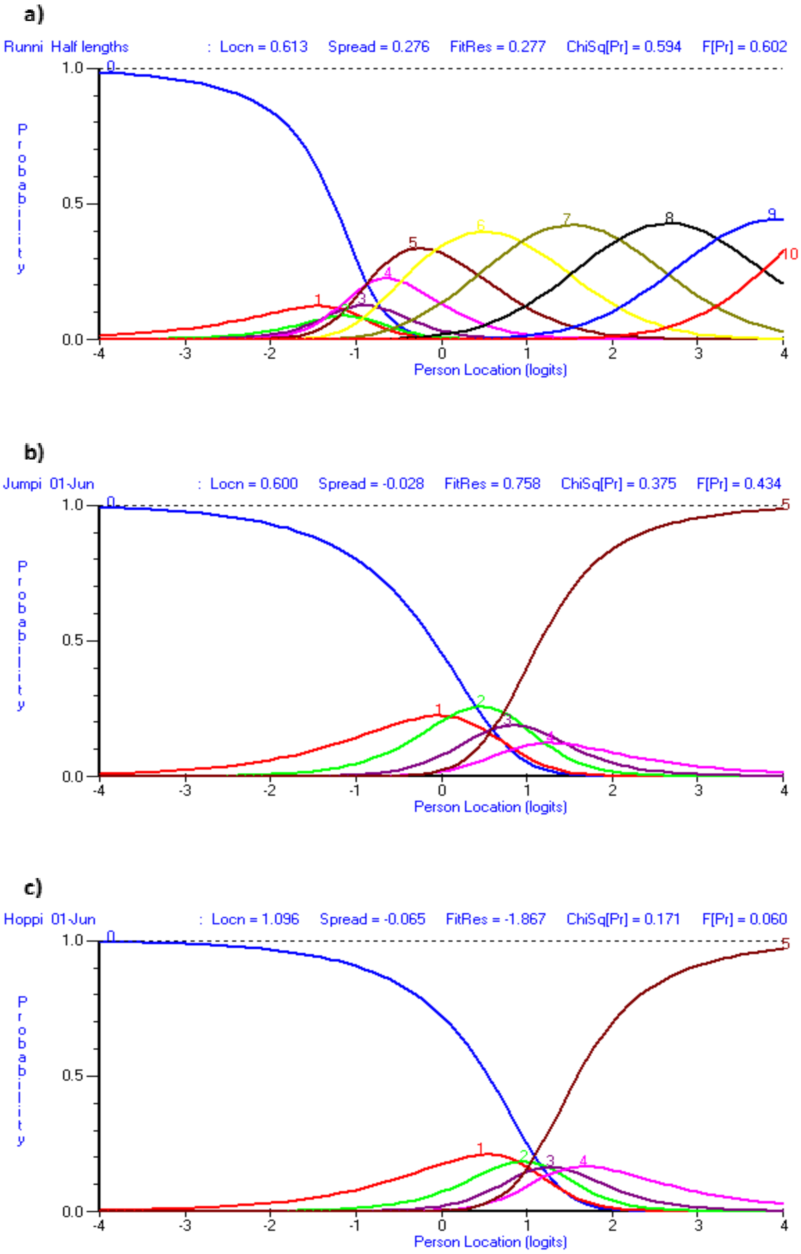


Figure 29 - category probability curves from study 3, both schools initial analysis

NB: a) shows disordered thresholds for running; b) shows disordered thresholds for jumping and c) shows disordered threshold for hopping. Graphs were generated by RUMM 2030 software.

Table 31 – Summary Statistics for Study 3

	Item location		Person location		Item fit residual		Person fit residual		Chi-square interaction			Person Separation Index (PSI)		Unidimensionality			
Analysis	*m*	SD	*m*	SD	*m*	SD	*m*	SD	Value	*df*	*p*	With Extrms	No Extrms	Number of sig tests	Out of	%	Lower 95% CI
Both - Initial	0	.97	.7	.61	.26	1.15	-.23	.95	55.39	42	.08	.64	.64	25	421	5.94	.04
Both - Rescore	0	1.06	.64	.72	.13	1.05	-.25	1	56.11	42	.07	.62	.62	25	421	5.94	.04
One – Initial	0	.87	.75	.64	.17	.86	-.22	.90	19.56	14	.14	.67	.67	11	168	6.55	.03
One - Rescore	0	.95	.68	.75	.12	.77	-.24	1.02	20.42	14	.12	.64	.64	9	168	5.36	.02

4.4.2.3 Both Schools - Rescore Items

As running, jumping and hopping all had disordered scoring thresholds in the initial analysis, these items were rescored for a second analysis. As can be seen in Figure 29, participants were never more likely to score 1-4 full lengths than zero or five full lengths in the running activity. Categories 1-4 were therefore collapsed into a single category to explore the effect this would have. Following the same reasoning, after reviewing Figure 16, jumping and hopping raw scores (i.e. how many boxes they completed) was rescored into the following simplified response categories, which were selected to better reflect gradations in response: 1 - cannot do the activity, 2- can do the activity up to the half way (line 3), 3- can do it past half way but cannot finish it and 4- can complete the activity.

FUNMOVES, after this re-scoring fit the Rasch model ($\chi^2(42)= 56.11$, $p = .07$) and was unidimensional (5.94% of tests, 95% *CI* = .04, .08), with no items displaying local dependency (limit $r = .04$). However, these changes in scorings also caused some issues with the Rasch analysis. The internal consistency dropped further below acceptability (PSI = .62), hopping became a mis-fitting item when accounting for Bonferroni adjustment ($F(6,410)=4.14$, $p<.001$) and uniform DIF was found for year groups for the hopping ($F(5)=4.97$, $p<.001$) and balance ($F(5)=4.75$, $p<.001$) activities, as well as gender DIF for running (Running ($F(1)=25.15$, $p<.001$), kicking ($F(1)=11.22$, $p<.001$) and balance ($F(1)=16.27$, $p<.001$). An ANOVA found significant differences between mean logit location of year groups (see Table 32; $F(5,415)=48.16$, $p<.001$) and between the scores of typically developing children and teacher identified children (see $F(1,419)=12.91$, $p<.001$). An ANOVA also showed no significant difference on performance on FUNMOVES between males and females ($F(1, 419)=.60$, $p=.44$).

Table 32 - Descriptive statistics for logit location on FUNMOVES by year group for study 3, both schools

Year group	*n*	*m*	*SD*
Year 1	75	-0.05	0.58
Year 2	65	0.34	5
Year 3	70	0.44	0.58
Year 4	72	0.9	0.49

Year group	*n*	*m*	*SD*
Year 5	70	1.1	0.6
Year 6	69	1.43	0.7

Table 33 - Descriptive statistics for logit location on FUNMOVES by motor ability for study 3, both schools

Motor Problems	*n*	*m*	*SD*
No	413	0.65	0.71
Yes	8	0.26	0.83

Table 34 - Descriptive statistics for logit location on FUNMOVES by gender for study 3, both schools

Gender	*n*	*m*	*SD*
Male	196	0.67	0.71
Female	225	0.61	0.73

4.4.2.4 One School – Initial Rasch Analysis

With re-scoring modification proving ineffective at improving the Rasch analysis results in this study, it was decided to explore what effect excluding the data from the school that had had not complied with the implementation checks, would have on analysis. The data from this school was deemed unreliable, and potentially invalid as FUNMOVES was not delivered in the intended manner in this school (i.e. it was not teacher delivered/ scored in some case). The revised sample for subsequent analyses therefore comprised of 168 children (70 male, *m* age= 8.42 years, *SD* = 1.92 years) from the one remaining school, in which teachers identified five children as having potential motor skill difficulties.

Removing the non-compliant school's data resulted in FUNMOVES being a unidimensional measure (6.55% significant tests; 95% *CI* = .03, .1) which had a good fit to the Rasch model ($\chi^2(14) = 19.56$, $p = .14$) and just below acceptable internal consistency (*PSI* = .67). Additionally, there were no misfitting items, local dependency (limit $r = .05$) or item response bias. As with the analysis that included both schools, disordered thresholds were still found for running, jumping and hopping in this new analysis.

4.4.2.5 One School – Rescore Items

The scoring of running, jumping and hopping were therefore rescored and reanalysed for a final time in this sub-sample to see if this would ameliorate the disordered thresholds observed. For running, scores 1-5 were combined as no child was more likely to get 1-5 than 0 or 6 (see Figure 31). For jumping and hopping scores were changed to: 1 - cannot do the activity, 2- can do the activity up to the half way (line 3), 3- can do it past half way but cannot finish it and 4- can complete the activity. These categories were chosen based on the frequency of responses within original scoring categories.

Jumping and hopping still presented with disordered thresholds, however, when accounting for 95% confidence intervals, the thresholds were ordered. These modifications also improved the unidimensionality of FUNMOVES (5.36% significant tests; 95% *CI* = .02, .09). Additionally there were no misfitting items, or local dependency (limit *r* = .04), and this version of FUNMOVES fit the Rasch model ($\chi^2(14)$= 20.42, *p* =.12). The internal consistency (PSI) was lower at 0.64 than the minimum usually accepted for comparisons between individuals (0.7). However, this PSI value is acceptable in a screening tool for differentiating between children with age-appropriate motor competence and a group of children with poor motor skills. A person-item map for study three can be found in Figure 30.

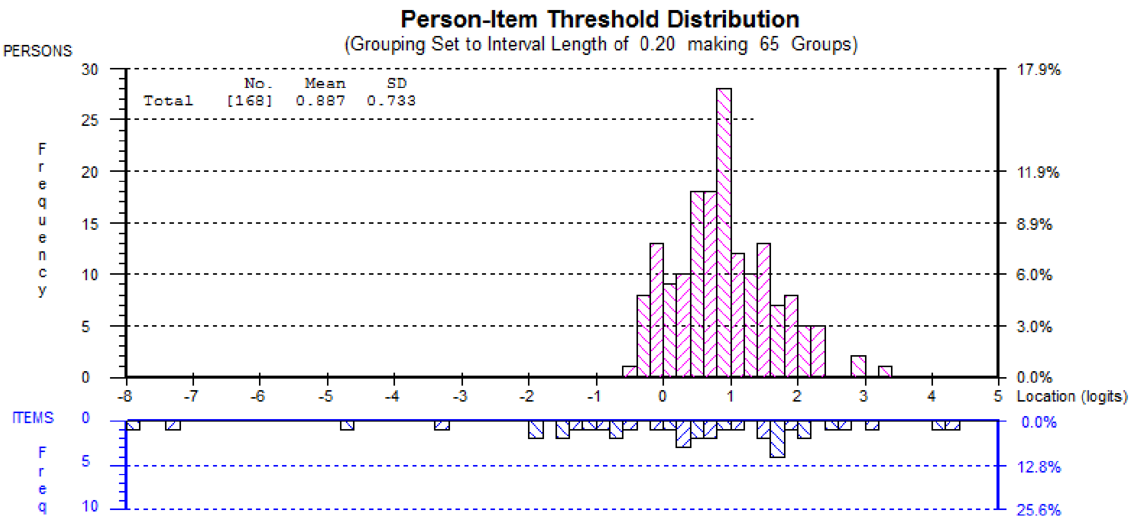


Figure 30 – Person-Item Map for the finalised Version of FUNMOVES

Item response bias was identified for balance, by gender (Balance *F*(1) = 9.83, *p*= .002), however, the differences between boys and girls were minimal and only evident for children who scored at the top end of the scale on FUNMOVES, thus the activity was not split (i.e. remained the same activity and scoring for both genders). An ANOVA showed that there was a significant difference between the scores obtained by year groups (see Table 35 ; *F(5,162) = 25.79, p<.001*), in which mean logit score increased with each year group. Additionally, there was a significant difference in mean logit scores between children identified prior to testing as potentially having motor problems, and ‘typically developing’ children (see Table 36; *F*(1,166) = 5.42, *p*=.02), in which teacher identified children performed significantly worse on FUNMOVES. It is, however, important to note that there were only 5 children identified as potentially having difficulties with motor skills, so caution needs to be taken when interpreting this result to avoid over-interpretation. Analysis also revealed that gender did not impact mean logit scores (see Table 37; *F*(1,166) = 1.66, *p* = .20). The final version of FUNMOVES allowed teachers to measure the FMS of a whole class of 30 children in 42 to 58 minutes.

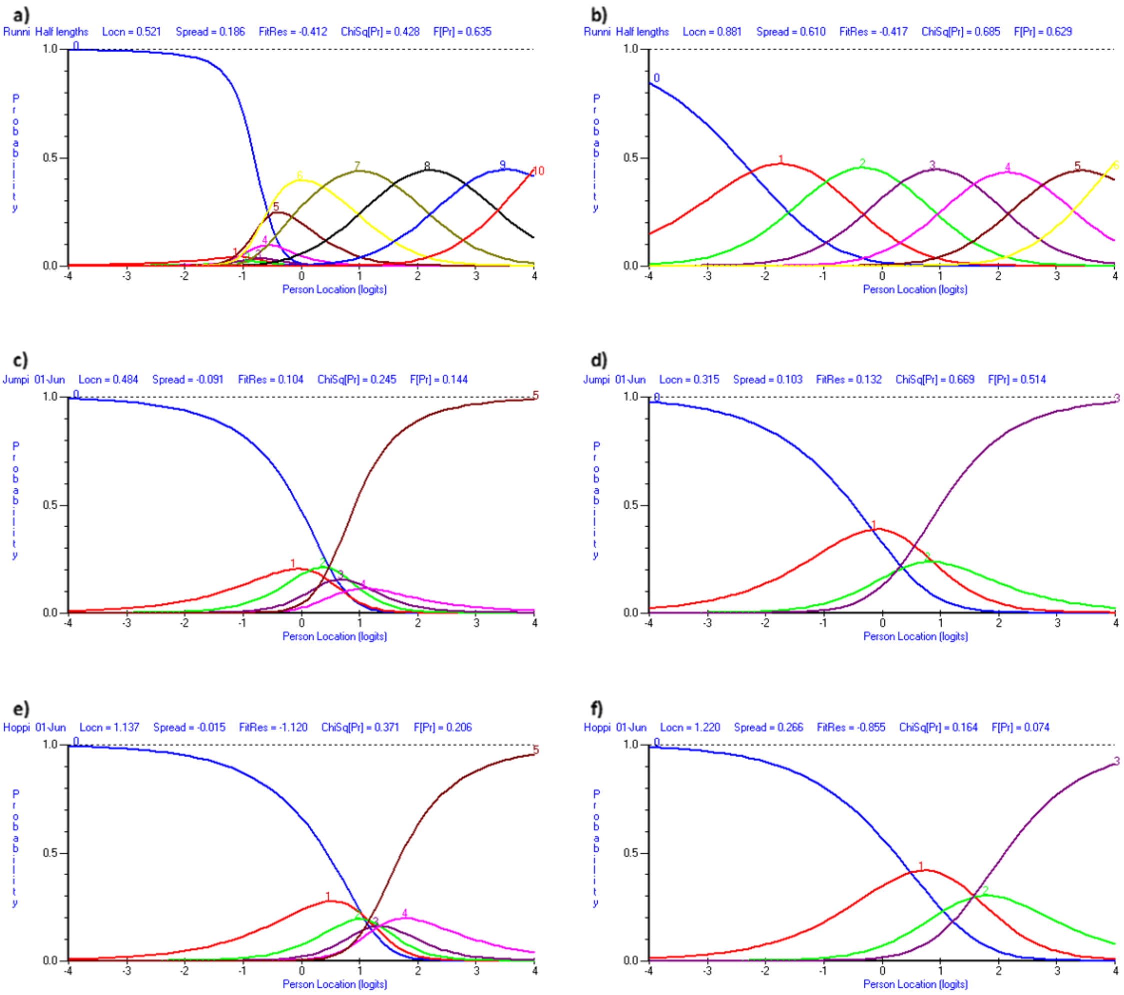


Figure 31 - category probability curves from round three of testing, one school

NB: a) shows disordered thresholds for running and b) shows those categories as ordered once scores 1-5 were combined. c) shows disordered thresholds for jumping and d) shows those categories as ordered (within 95% confidence intervals) once categories 1 and 2 were combined and 3 and 4 were combined. e) shows disordered thresholds for hopping and f) shows those categories as ordered (within 95% confidence intervals) once categories 1 and 2 were combined and 3 and 4 were combined. Graphs were generated by RUMM 2030 software.

Table 35- Descriptive statistics for logit location on FUNMOVES by year group for study 3, one school

Year Group	***n***	***m***	***SD***
Year 1	28	-0.06	0.61
Year 2	27	0.35	0.45
Year 3	26	0.34	0.46
Year 4	29	0.94	0.48
Year 5	27	1.04	0.59
Year 6	31	1.38	0.75

Table 36- Descriptive statistics for logit location on FUNMOVES by motor ability for study 3, one school

Motor problems	***n***	***m***	***SD***
No	163	0.71	0.75
Yes	5	-0.08	0.45

Table 37- Descriptive statistics for logit location on FUNMOVES by gender for study 3, one school

Gender	***n***	***m***	***SD***
Male	70	0.77	0.81
Female	98	0.62	0.7

4.5 Discussion

This chapter aimed to develop a school-based screening tool of FMS ability for Primary school children that was both theoretically and psychometrically sound and feasible for use in schools.

4.5.1 Psychometric Properties

When considering the psychometric properties of the final version of FUNMOVES trialled in Study 3, scored using revised criteria, this assessment tool was unidimensional, fit the Rasch model, and had no misfitting items or local dependency.

Additionally, results consistently revealed that children identified by teachers as potentially having motor difficulties prior to testing scored significantly worse than their peers. This was the case across all three iterations of the assessment which suggests that FUNMOVES can differentiate between abilities. The results of these ANOVAs should, however, be interpreted with caution, as there were very few children identified by teachers in the three studies (7% of the sample in Study 1, 14% in Study 2 and 3% in Study 3). The small sample sizes in the ‘motor difficulties’ group may have inflated the results. It therefore remains important to test the ability of FUNMOVES to differentiate between typically developing children, and those objectively identified as having motor problems using pre-existing, valid and reliable measures of FMS such as the TGMD (Ulrich, 1985, 2000, 2016) or the MABC (Hendersen et al., 2007; Henderson et al., 1992).

Moreover, upon taking part in testing, schools were given reports which detailed how each child performed on the activities within FUNMOVES compared to children in the same year group. In the course of preparing these reports, it became apparent to the researcher that there was a substantial number of children that were being missed or misidentified by their teacher. One example was a child who had ASD that the teacher anticipated would perform badly on the tool, who were then surprised that they scored in line with their peers. This is perhaps unsurprising, given that a recent review highlighted discrepancies between ratings of children’s motor abilities when teacher rating (via questionnaire) were compared to ratings derived from physical assessments (Bardid, Vannozzi, et al., 2019). Chapter 3 would suggest that this may, in part be due to a lack of knowledge amongst teachers regarding FMS. Thus, it is likely that children exhibiting more obvious difficulties with motor skills may be identified utilising questionnaire methodology, however the discrepancies highlight the importance of physical assessment to identify all children with poor motor skills so they can be provided with additional support.

In all three studies within this chapter, it was revealed that there was no meaningful differences between the average performance of boys and girls on FUNMOVES. This is in contrast to research that found evidence for gender differences in FMS ability (Bolger et al., 2020; Goodway et al., 2010; Kokštejn et al., 2017). As was alluded to in Chapter 1, the effects found in these earlier studies were mixed, however, it is most often reported that girls outperform boys on locomotor tasks and the opposite for object control tasks. There was no evidence of item-response bias in relation to gender for any of the locomotor (running, jumping and hopping) or object control (throwing and kicking) in Study 3. This contradicts some findings discussed in Chapter 1, which proposed that gender differences in object control ability may in part, be explained by sociocultural differences in upbringing, in which boys spend more time playing ball sports (Barnett et al., 2010; Thomas & French, 1985). The lack of a difference within FUNMOVES' object control tasks is plausible if one considers the equipment involved though. The use of beanbags instead of balls means it is possible that both genders will have been afforded similar opportunities to practice these skills previously. For example, throwing beanbags is a common activity within P.E. lessons, so both boys and girls should have had equal opportunity to practice this previously. Whereas kicking practice is often done with balls, both in P.E. and in sports specific sessions, so it is likely that kicking beanbags will have been equally novel for both boys and girls. The results of study 3 show an item-response bias for the balance activity by gender, in which males performed marginally worse than females, despite having the same overall ability levels. This pattern has been found by studies previously (Mickle et al., 2011; Rodríguez-Negro et al., 2019; Singh et al., 2015; Van Waelvelde et al., 2008), however as was discussed in Chapter 1, stability skills are less commonly evaluated so there is limited research exploring why this might be the case. It is, however, important to note that the gender differences found for the balance activities within FUNMOVES were only present for children achieving the highest scores on the activity (i.e. those with the greatest levels of FMS ability). As FUNMOVES was designed to screen children with FMS difficulties, the measure was therefore not modified, as there was no gender differences found for children performing poorly in these balance activities.

It is important to note that the scoring thresholds for running were disordered in the final study, and researchers decided that although modifications were made in the final study, these modifications would not be carried forwards with finalised version of FUNMOVES. This decision was made by the working group due to the growing body of evidence that suggests SES has an impact upon FMS ability (as is described in more detail in Chapter 1). Studies often find that high SES children are more proficient than their low SES peers (Hardy et al., 2012; Morley et al., 2015). The school whose results were analysed in isolation in Study 3 was from a wealthier area (Index of Multiple Deprivation (IMD) Decile rank 6) compared to the schools in Studies 1 and 2, both of which were in neighbourhoods with an IMD Decile rank of 1. As the children in the final school would be expected to, on average, perform better than children in these earlier studies, the fact that they were not using the first five scoring categories (i.e. between one and five lengths) is perhaps unsurprising. In a similar vein, it is also notable that the final school had many physical activity initiatives in place, including playground monitors who were responsible for leading active games during break times. With both of these potential sources of sampling bias in mind, it was believed that removing scoring categories (1-5) that were suggested to be redundant in the final analysis in Study 3 may be detrimental for measuring running ability in lower SES schools, as well as those with less active policies. Therefore, to ensure FUNMOVES remained suitable for use in all schools, the scoring categories established in Studies 1 and 2 were retained, where no such threshold issues were. Although there were no issues with running scoring in the first two studies (after changing from metres run to the number of lengths completed in Study 1), it will be important for future research studies to establish whether this scoring is indeed the most appropriate one to recommend for use across a wider range of schools.

4.5.1.1 Limitations in Evaluating Psychometric Properties

One limitation of FUNMOVES is that the final PSI value for internal consistency was lower than 0.7, which is widely acknowledged as the limit for having acceptable internal consistency in the literature (Fisher, 1992). As can be seen in Figure 30, many of the participants in the sample were above average ability (with average being 0 on the logit scale). This figure also shows relatively narrow levels of variability in ability levels in this sample, with a large proportion of the children tested falling between zero and two on the logit scale. As only approximately half of the activity levels fell within this range, there was not enough measurement points to differentiate between the bulk of the activities. This explains why the PSI was lower than accepted. However, there were measurement points spanning the full range of abilities tested, as well as activity levels beyond the scope of the sample tested (i.e. appropriate for children of much poorer ability, including those with a logit location of -8, and those of better ability, who would fall at 4.5 on the logit scale). As the scoring thresholds were spread sufficiently along the scale, this suggests that it would enable children of all abilities to be measured by the activities on FUNMOVES. Moreover, it demonstrates that the assessment tool would be able to identify children that should be highlighted for further investigation by a screening programme (i.e. those with poor FMS). Despite this, it will be crucial for future research to evaluate whether FUNMOVES can indeed consistently identify children that have poor FMS ability, as measured by well-established measures of FMS ability such as the TGMD (Ulrich, 1985, 2000, 2016), the MABC (Hendersen et al., 2007; Henderson et al., 1992) or the BOT (Bruininks, 1978; Bruininks & Bruininks, 2005).

Secondly, the scoring format for the finalised version of the jumping and hopping in activities has not yet been tested within schools. After two studies, the scoring thresholds for these activities were still disordered. Upon discussion amongst the team, it was decided that this may reflect the fact that the ‘levels’ within these activities were not increasing in difficulty; rather children were required to do the same task five times. Although this may have had an impact upon strength or balance (e.g. how long a child can stay stood on one leg), the results from these earlier studies suggested these factors were not sufficient to differentiate between FMS ability levels. The working group therefore decided to increase the difficulty between these levels further, by incrementally reducing the size of the target area for children to land within on each line. It was hoped that this would improve the response category threshold ordering for hopping and jumping. Although the use of six scoring categories for these activities was not appropriate, modifying the scoring to have four categories instead of six allowed fit to the Rasch model. This allows confidence that the new categories will be appropriate for other samples, as unlike CTT analyses, Rasch analysis is not dependent on the sample (Hambleton & Van der Linden, 1982). Despite this, it will be important to evaluate these scoring categories in a subsequent studies to build a larger corpus of evidence corroborating their appropriateness.

Finally, it is important to recognise that these three studies are only a first step in validating FUNMOVES. Although the rigorous development and evaluation via Rasch analysis builds confidence in the content and structural validity of FUNMOVES, it will be important to ensure that all aspects of the COSMIN checklist (Mokkink et al., 2010b) are evaluated before its use can be unreservedly recommended for use in schools. This degree of evaluation is particularly important, given the fact that Chapter 2 highlighted that previous studies have been selective in which aspects of validity and reliability have been measured. This means that for most assessments there are often several psychometric properties that remain unevaluated. In addition, due to the group nature of the assessment, further research will also be needed to examine whether external factors, such as attention, or position on the grid that a child is assessed, have an impact upon FMS ability as measured by FUNMOVES.

4.5.2 Feasibility

When considering feasibility, Chapter 3 sought to review and adapt a set of somewhat arbitrary guidelines proposed by Klingberg et al. (2018). Using an online survey of Primary School teachers, opinions were gathered, prompting revisions to these guidelines based on empirical evidence gathered from those that universal screening in schools would directly impact. The revised guidelines set out at the end of Chapter 3 were as follows:

(i) assessments should be quick to implement, be that either less than ten minutes per child, or between 30-60 minutes per class
(ii) assessments should only utilise equipment that is readily available in schools, such as beanbags and chalk, or should provide schools with such equipment at no additional cost
(iii) space constraints in schools mean that the FMS of children should be able to be assessed within a small (≤5 m^2) space, either indoors or outdoors
(iv) assessments should be implementable by two members of teaching staff
(v) teaching staff should require minimal training to enable them to assess the FMS of their pupils (maximum of half a day)
(vi) school-based assessments of FMS should be product-oriented

When considering guideline (i), the finalised version of FUNMOVES fits within this remit as it was able to measure the FMS of a whole class between 42 and 58 minutes. This will ensure that testing can be done within the timeframe of a P.E. lesson, thus lessening the burden on time pressures within schools (Routen et al., 2018).

In relation to guideline (ii), FUNMOVES was designed to only use equipment that teacher responses in Chapter 3 indicated would be readily available in schools (i.e. 25 beanbags and a stopwatch). The research team, did however, decide to use electrical tape instead of chalk, which was also identified as being commonly found within schools in Chapter 3. This variation in equipment was decided upon to allow for ease of implementation whilst testing whole schools in a short amount of time. As classes were often tested back to back, it removed the need for teachers or researchers to re-draw the grid every time, as the tape was more long-lasting and meant that researchers only needed to re-touch the grid at the start of each day. The electric tape was provided for schools in this instance, so that schools were not having to pay to participate, however it would cost a school less than £5 to buy enough tape to implement FUNMOVES across all year groups, so this cost should not be considered burdensome, even in the context of limited school budgets (Perera, 2020). In addition, it is possible to implement FUNMOVES using a chalk grid. This was trialled for the first version of FUNMOVES, which was written up for a Masters dissertation. Therefore, if school budgets were stretched, there remains the option for schools to use this more readily accessible resource to create the grid.

In relation to guideline (iii), the activities within the assessment are all contained within a five metre squared grid, which is in alignment with the space guideline, as 87% of Primary School teaching staff believed their school had this amount of suitable space indoors, and 98% outdoors. All testing for these three studies were conducted indoors, in school sports halls. It is therefore important to note that the finalised version of FUNMOVES has not been tested outdoors on a playground. Prior to the three studies detailed above, FUNMOVES was piloted on one school for a Masters dissertation. Due to a lack of indoor space in the school, FUNMOVES was completed outdoors. Although the activities varied slightly from those included in the finalised version, they were largely similar and were implemented successfully in this outdoor setting. One consideration that will need to be made, is whether the revised/alternative scoring criteria will need to be developed to validly assess performance the object control tasks (both throwing and kicking) when used outside. For these tasks, it is likely that the beanbag will not travel as readily on an uneven outdoor concrete surfaces (e.g. school playgrounds) when compared to sports hall floors. This may impact upon the strength needed for a child to kick or throw a beanbag to the further boxes because those which would land slightly short and slide into the target zone in a sports hall, likely won’t outdoors. It is, however, important to consider the purpose of the throwing and kicking activities. These activities were designed to require children to moderate the power of their throws/kicks to reach a number of targets, rather than just measuring the distance a child could kick. This nuance was intentional because research has shown that for a child to be able to participate in physical activities, they do not solely need to be able to throw forcefully for distance, but they are also required to throw accurately to target locations (Hamilton & Tate, 2002). So, although children may need to be more precise when throwing or kicking outdoors, it is still plausible that these activities will function as intended without the need to modify how they are scored, as children will still need to moderate the force exerted on the beanbag to reach a target location. Finally, to reach the final target, a child only needs to be able to kick a beanbag just over four metres in length. It is imperative for further research to be done to establish the effect of the surface on scores though, as it may impact on the ability to use norms data to identify children with difficulties. It may be the case that different norms data is needed for indoor and outdoor versions of these activities.

When considering guidelines (iv) and (v), two members of teaching staff were able to implement FUNMOVES after an hour of training. The results of Study 3’s fidelity checks revealed that teachers on the whole were able to implement FUNMOVES accurately, with researchers judging that teachers were scoring correctly. There were, however a number of instructions for activities that teachers needed to be reminded of. This likely reflects improvements needed in clarity with which they are communicated during teacher training and within the manual. It will also be important to test whether teachers can independently implement FUNMOVES once these changes have been made. Finally, FUNMOVES is product-oriented (guideline vi), as it measures the outcome of movements, for example, the number of beanbags thrown to a target box. FUNMOVES therefore meets all teacher-defined feasibility criteria, which should improve the likelihood of its uptake by schools.

Recently, an expert panel, consisting of academics in motor development and physical education, as well as specialist PE teachers and coaches with experience improving children’s motor ability, took part in a Delphi study to gain consensus about what should be included in school-based assessments of FMS (Van Rossum et al., 2021). The included experts were asked to rank the importance of a range of FMS, make judgements on the number of FMS from each sub-category (locomotor, object control and stability) should be included, and how they should be scored. On average, the experts stated that there should be four activities which measure stability, five that measure locomotor skills and five which evaluate object control skills. Consequently, the authors decided to recommend the inclusion of fourteen skills in any FMS battery: four stability (one leg balance, walking along a beam, front support and sideways roll) five locomotion (run, hop, horizontal jump, side stepping and skipping) and five object control (two handed catch, underarm throw, overarm throw, kicking a ball and bouncing a ball whilst stationary). The authors then confirmed by a majority vote, to recommend the use of process-oriented measures within schools. FUNMOVES does not align with the guidelines outlined by this study. It includes significantly fewer activities (six, rather than fourteen), only four of these activities are included in the list outlined in the paper (run, hop, underarm throw and one-legged balance), and it measures ability using product outcomes, rather than process. FUNMOVES also includes kicking, but this activity utilises beanbags instead of a ball. Similarly, FUNMOVES also in includes jumping, however the focus is on moving through space and being able to stop and balance, rather than jumping sideways.

Although consultation with experts allows for strong face validity, there are, however, a number of issues with utilising this approach to designing an assessment tool. Firstly, the authors claim that it is important to consider the level of knowledge of the end users (i.e. UK primary school teachers) when deciding whether to utilise product or process oriented activities to measure FMS ability (Van Rossum et al., 2021). However, rather than consulting teachers on the two types of assessment, they relied on expert panel members' interpretation of teachers' presumed abilities, which may not be accurate. Particularly given that they acknowledge that there is a lack of P.E. specialists in the UK, and that, most teachers will have only received six hours of training on how to deliver the P.E. curriculum (Harris et al., 2012). The authors also acknowledged the lack of confidence teachers have in their ability to deliver assessments based on their previous research consulting teachers (van Rossum et al., 2018). The lack of knowledge that teachers have was also evident in the results of Chapter 3, so it is presumptuous to assume this method of assessment will be suitable for teachers without consultation. Moreover, consensus was not achieved for all activities with regards to how activities should be measured, with some being voted more suitable for product scoring, and others process. Secondly, although the included activities are hypothesised to measure the same overarching construct (i.e. FMS) based on the included experts' opinions, it is impossible to ascertain whether this is actually the case without rigorous psychometric testing of the proposed FMS measure. For example, the experts included walking along a beam in their list of activities. FUNMOVES in Study 1 included walking along the line, a similar activity, however this did not fit the Rasch model. In fact, only following its removal was unidimensionality improved. Herein lies the advantage of using objective evaluations within the development of tools, to help ensure their psychometric properties. It allows systematic evaluation of the feasibility and appropriateness of included tasks, rather than reliance on opinion.

4.5.2.1 Limitations in Evaluating Feasibility

Firstly, despite the fact that FUNMOVES is feasible when compared to pre-determined criteria, including the guidelines outlined in Chapter 3, and those specified by Klingberg et al. (2018), feasibility was not formally evaluated in these studies. It will be crucial to conduct qualitative studies with teachers that have implemented FUNMOVES in schools, to explore their thoughts and opinions on feasibility and acceptability. It will also be important to evaluate the ability of school staff to implement FUNMOVES accurately, without the assistance and presence of the research team. The three studies included in this chapter all had researchers present to rectify mistakes made by teachers. This was a conscious decision to ensure that the activities being evaluated and validated by Rasch analysis were implemented as intended. In a universal screening context, however, researchers will not be present, even in this observing role. Given observations of some teachers omitting certain instructions crucial to the correct implementation of FUNMOVES, it will be important to update the teacher training session and the physical resources that teaching staff receive to accompany these sessions (i.e. the manual and score sheets) to ensure clarity and ease of execution.

Secondly, it is important to note that FUNMOVES, in a whole class format, was not feasible for children in their first formal year of education (Reception; children aged between 4 and 5 years old). This age group was not tested beyond Study 1 as the Reception teachers believed that it would be difficult to keep the class on task, and thus the children were tested in groups of five instead, which is not the intended delivery method of FUNMOVES, due to increased time demands this would generate. Testing in these small groups was, however, effective, as it allowed children to better comprehend the activities, and it was easier for staff to manage the group and score the activities simultaneously. This methodology also meant that extra staff were required to supervise the children waiting to be assessed who usually remain in the classroom. This was not problematic for the school tested in Study 1, due to there being extra support staff available for Reception year groups. However, this may not be the case for all schools. As early identification of motor skill difficulties has been found to be beneficial (Missiuna et al., 2003) future research would benefit from evaluating whether the finalised FUNMOVES battery of activities implemented in this way is valid, reliable, and feasible to be implemented in smaller groups for Reception children, and how results relate to performance at later ages (i.e. when assessment is conducted as a whole class).

4.6 Conclusion

After three rounds of iterations, FUNMOVES enables two members of teaching staff (e.g. a teacher and a teaching assistant) to assess the FMS ability of a whole class (approximately 30 children) in under an hour, in a small space (5x5m squared), using resources available in schools (or cheap to buy resources such as electrical tape) after a short staff training session (approximately an hour). FUNMOVES was found to have strong structural validity, and meets guidelines for feasibility for use within universal screening programmes in schools, which were proposed in Chapter 3.

A more collaborative approach to FMS assessment, linking healthcare and education services, has the potential to expedite access to assessment and intervention, and ultimately improve outcomes for children. Before FUNMOVES can be recommended for use in this context, it will, however, be vital to further evaluate its (i) feasibility and acceptability through qualitative data collection with teaching staff that have implemented the assessment and (ii) additional psychometric properties, such as differing forms of validity and reliability.

Chapter 5
Protocol for the Validity, Reliability, Feasibility and Acceptability of FUNMOVES

5.1 Background / Rationale

The structural validity of FUNMOVES was established in Chapter 4, through rigorous development utilising Rasch analysis. This allows confidence that all activities are measuring the same over-arching construct (FMS). However, further work is required to establish the other psychometric properties listed on the COSMIN checklist (Mokkink et al., 2010a). Such further evaluations are necessary before FUNMOVES can be recommended for use in universal screening programmes. Similarly, although FUNMOVES was designed to adhere to feasibility guidelines (developed in line with teacher opinions), and this is a good first step (see Chapter 3 for details), research needs to be conducted to gain insight into teacher experiences with implementing FUNMOVES in a school environment. This is vital to better understand how acceptable it would be. This chapter outlines a protocol to address the remaining aims and objectives outlined in Section 1.6 (to evaluate the validity, reliability, feasibility and acceptability of the new assessment tool).

This protocol was due to be actioned between March and July 2020, within the timeframe of this PhD, however the COVID-19 pandemic limited and (during lockdowns) prevented access to schools. Schools were closed between March and June 2020, and again December 2020 and January 2021 due to a rise in cases. When schools re-opened, access was limited due to protocols put in place by schools, such as classroom bubbles and a blanket rule on no external visitors. The pandemic has, however, highlighted the need for a universal screening tool of FMS ability. Research has shown that children have been less active (Bingham et al., 2021), and have become less proficient at FMS (Pombo et al., 2021). OFSTED have also noted concerns over children’s physical abilities upon their return to schools (Ofsted, 2020).

5.2 Project Aims and Objectives

The primary aim of this research is to establish whether FUNMOVES is suitable for use in universal screening programmes in primary schools.

Objective 1: To evaluate the remaining psychometric properties of FUNMOVES from the COSMIN checklist (inter-rater reliability, internal consistency, test-retest reliability, concurrent validity, predictive validity and hypotheses testing validity).

Objective 2: To understand teachers' opinions of FUNMOVES and its usability within the school environment.

5.3 Work Package 1 – Assessing Psychometric Properties (Validity and Reliability)

5.3.1 Participants

5.3.1.1 Sample size and power

A sample size estimate calculation was conducted using the 'pwr' package in R Studio. A significance level of .05, and power value of .8 was specified to detect a medium effect size (.3). The calculation estimated a minimum of 84 participants (primary school students) for each of the quantitative validity and reliability studies.

5.3.1.2 Recruitment

Primary schools will be recruited by utilising contacts within the Born in Bradford (BiB) and the local Department for Education Opportunity Area, who have well-established links to schools within the Bradford district area. Additionally, a formal application will be submitted to the Centre for Applied Education Research (CAER) executive committee, who work with and have influence in, a large number of schools in the area. Schools will be invited to take part in the study by (i) a poster emailed to the schools detailing the purpose of the study, what it entails and the benefits for schools (see Appendix I) and (ii) a follow-up face to face meeting with a trained researcher about the study. This meeting will be used to discuss consent, logistics for testing (e.g. dates, times and space requirements), as well as to answer any questions or concerns they may have.

Due to the group-based nature of FUNMOVES (class-based assessment), head teachers and class teachers will consent to classes within the school participating and subsequently parents will be given information regarding the purpose of the study prior to testing and an opt-out consent form they can use to inform the school to withdraw their child from participation. This methodology was chosen as Born in Bradford (BiB) regularly use opt-out consent, and like to be consistent in their approach across nested studies (of which this will be one). As well as this, schools in Bradford have a high proportion of children from disadvantaged families, which are less likely to return opt-in forms. This then further disadvantages children from these families as they don't get to participate in programmes that are designed to help with various developmental difficulties, such as fundamental movement skills (as is the case with this study). Verbal assent will also be sought from the child, on the morning of testing.

5.3.1.3 Eligibility Criteria

To be included within the study, children must be: (i) aged between five and eleven years old (school years 1-6). Children will be unable to participate if (i) their parents return opt-out consent forms or (ii) they do not verbally assent to take part on the day(s) of testing.

5.3.2 Design

The schools that are recruited will commit to testing all pupils in years 1-6 classes using FUNMOVES. To reduce the burden on schools, they will be recruited to also complete additional measures from one of two pathways (see Figure 32). The first pathway would involve a school doing test-retest reliability within two classes from either (i) year 1 and year 4, (ii) year 2 and year 5, or (ii) year 3 and year 6. To ensure sufficient power for analysis, and data across all year groups this would require recruiting three one form entry schools as a minimum.

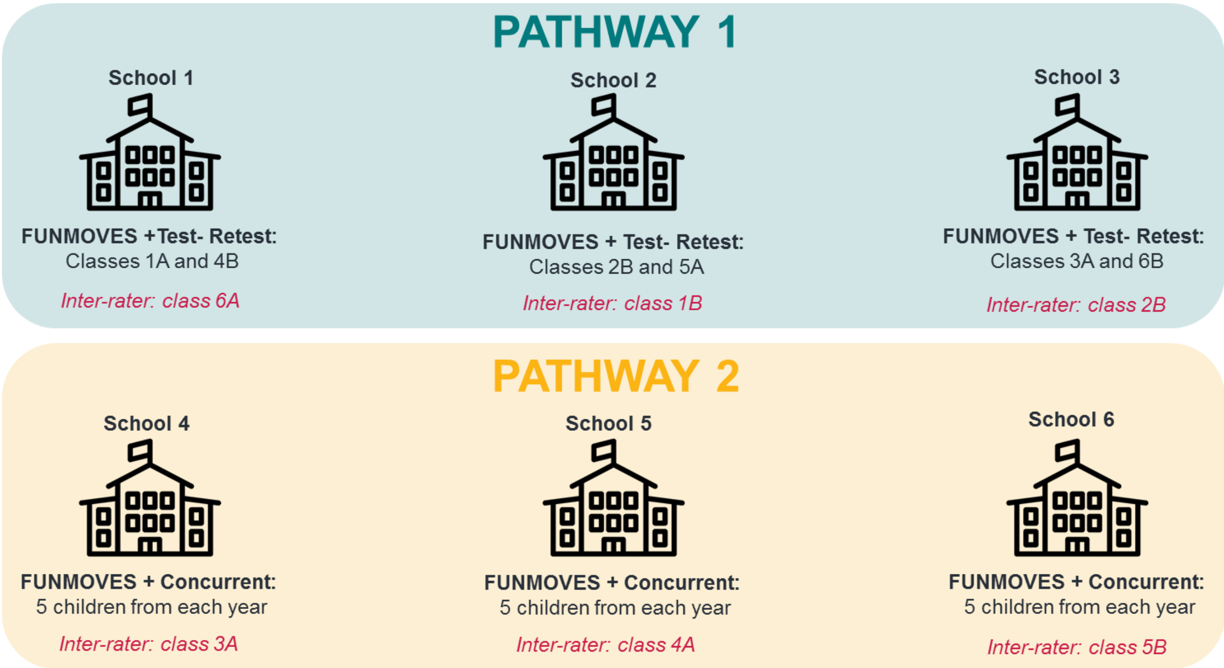


Figure 32 – Recruitment strategy for work package one

For the second pathway, three further schools will be required, from which six children within each year group will be randomly selected (using a random number generator to select participants based on their study ID number). These children will be assessed using the Movement Assessment Battery for Children (MABC).

Schools in both pathways will also allow researchers to evaluate inter-rater reliability at the time of initial testing within one class, from one year group. Each of the six schools will contribute a different year group for inter-rater reliability data, to ensure that the six different year groups of interest are covered by the six schools involved in the study. For an example of how schools might be distributed across these different sub-studies following recruitment, see Figure 32.

5.3.3 Measures

5.3.3.1 Demographics

Researchers will ask the school for the following demographic data:

- Child name
- Date of birth
- Gender
- Home Postcode
- Disability and/or Special Educational Need (SEN)
- Class name
- Year Group
- Ethnicity
- Receipt of free school meals

The child's name will be utilised to make personalised reports for schools detailing how each child performed compared to children of the same age. Date of birth and year group will be utilised to ensure percentile ranks (i.e. how the children are performing on FUNMOVES compared to their peers) are calculated for the correct ages. Class name will be used to compile reports for each class. Gender will be used to evaluate differences between boys and girls, due to research suggesting these differences exist within FMS ability (which discussed in detail in Chapter 1) (Matarma et al., 2020). Similarly, SES differences are found within FMS literature (see Chapter 1 for more comprehensive discussion) (Barnett, Lai, et al., 2016), so home postcode (which will be used to calculate IMD decile) and receipt of free school meals will be used to evaluate SES differences in the recruited sample. Finally, Chapter 1 also discussed FMS differences by ethnicity (Adeyemi-Walker et al., 2018; Eyre et al., 2018). Ethnicity data will therefore be collected. As the ethnicity within Bradford is largely made up of two ethnic groups (White British and South Asian) who are often found to have different FMS ability levels, the differences between these two groups will be evaluated within this sample.

5.3.3.2 FUNMOVES

The finalised version of FUNMOVES, as described at the end of Chapter 4 will be utilised. All activities within FUNMOVES take place within a five by five metre grid, which allows a class to be split into five ‘teams’ so that five children (one from each team) can be tested simultaneously.

Figure 33 shows an overview of the activities included within the final iteration of FUNMOVES. To recap briefly:

Running - for this activity, children have fifteen seconds to run from the bottom line on the grid to the far line and back as many times as possible. They are scored by the number of full lengths they run – for example in Figure 33 the child would have scored 5.

Jumping – children perform multiple small jumps (outline of feet on Figure 33) to reach the first pink line and pause on the line (filled in feet on Figure 33) for 3 seconds before jumping to the next line. The pink ‘target zone’ on each line gets smaller each time. Children need to land and pause on the target zone for each line, with both feet. Children are scored by the zone (numbered down the left hand side of the grid) in which they are unable to do the task as instructed (e.g. cannot stop on the line and maintain balance, cannot jump to land both feet in the target zone, falls over etc.). The ‘zone’ will not refer to singular boxes, but rather the scoring categories outlined by the final Rasch Analysis in Chapter 4.

Hopping – the hopping task works in the same way as jumping, except children are required to hop and balance on one leg (which the child chooses) for the duration of the activity. The activity is scored in the same way – by the zone on the grid where they cannot complete the task as instructed. This may involve not being able to stop still on the line, putting their foot down etc.

Throwing – for this activity children try to throw (underarm) five beanbags, one into each box in their lane. For example the child in Figure 33 would have scored five points. This task is completed twice, once with their left arm and once with their right.

Kicking – This task is completed a similar way to throwing (i.e. children kick five beanbags along the floor, aiming to get one in each box in their lane. Again they are scored by the number of boxes in their lane filled by beanbags. This task is only completed once, and the child can choose which foot they want to kick with.

Balance – for this activity children are required to manipulate a beanbag whilst maintaining their balance in four different postures (illustrated in Figure 33). Balance 1 requires children to pass a beanbag around their body three times whilst standing with their feet together. Balance 2 requires the same manipulation of the beanbag but whilst standing on one leg (of their choice). For balance 3, children are required to pick up a beanbag from the floor, maintaining balance whilst on one leg. Balance 4 is the same as balance 2 (i.e. passing a beanbag around their body three times whilst standing on one leg), except this time they have to do so with their eyes closed. Children are scored by the number of balances they complete. Once a child has 'failed' a balance, they do not get scored for attempts at later, more challenging balances.

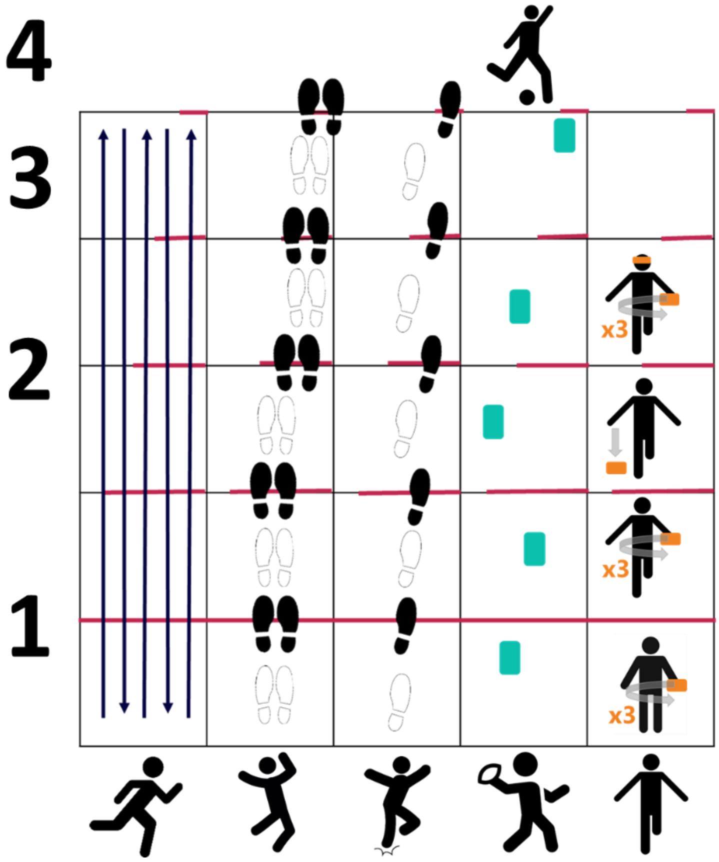


Figure 33 – Pictorial depiction of the activities within FUNMOVES

5.3.3.3 Movement Assessment Battery for Children (MABC)

The MABC (Hendersen et al., 2007; Henderson et al., 1992) will be utilised to measure the concurrent validity of FUNMOVES. This measure was selected to validate FUNMOVES against for a number of reasons. Firstly, Chapter 2 established that product-oriented and process-oriented assessments do not correlate very well. Research has recently established that these two types of assessment measure different aspects of FMS (Palmer et al., 2021). The systematic review in Chapter 2 indicated that the measure with the greatest evidence supporting its validity and reliability was the Test of Gross Motor Development (TGMD) (Ulrich, 1985, 2000, 2016) but this is a process-oriented assessment. Therefore, it was not considered to be a suitable comparison for FUNMOVES, a product-oriented measure. Of the product-oriented measures appraised in the systematic review, the MABC was the most comprehensively evaluated, with the MABC's performance having been evaluated for all ten COMSIN (Mokkink et al., 2010a) categories. In contrast, the BOT, the product-oriented measure with the next most evidence only had five psychometric properties established.

Additionally, the MABC is recommended as the 'gold standard' measure for diagnosing motor difficulties (Developmental Coordination Disorder) in Europe (Blank et al., 2012). Thus, the MABC is used within clinical settings in the UK, and therefore if children were to be referred for a more comprehensive assessment of their motor abilities, following screening using FUNMOVES, then this is the assessment that would be used. Thus, it is important that these two assessments identify similar children as having delayed motor skills, so that unnecessary pressure is not put on already over-stretched healthcare services.

5.3.4 Procedures

In alignment with the procedures in Chapter 4, teachers will receive an hour of training before testing to enable them to implement FUNMOVES. Training sessions will be interactive; they will involve a short introduction outlining what FMS are and why they are important, and then role play sessions where the teachers in attendance get a chance to practice (i) how to do the activities and (ii) how to score them. Following teacher training, two members of teaching staff will assess the FMS ability of their class using FUNMOVES.

For the classes within the inter-rater reliability 'condition', researchers will be present whilst testing is occurring. Researchers will score the children 'live', simultaneously with the teaching staff. No assistance will be given to teachers during testing, researchers will only observe and score the activities being undertaken. This methodology will enable an evaluation of how accurately teachers assess FMS ability comparative to 'gold standard' scoring.

One class from each year group (across three different schools) will be tested using FUNMOVES twice, two weeks apart, under the same testing conditions, to evaluate test – retest reliability. Testing will be undertaken in the same location, at the same time of day, by the same members of teaching staff on both occasions to mitigate for the potential impact of these extraneous variables.

Five children from each year group at three separate schools will be tested on both FUNMOVES and the Movement Assessment Battery for Children (MABC) subdomains: (i) Aiming and Catching and (ii) Balance, to evaluate concurrent and predictive validity. The Aiming and Catching and Balance subdomains within the MABC include measures of all three subdomains of FMS: Locomotion (jumping and hopping), Object control (throwing and catching) and Stability (one leg balance and walking along the line). The Manual Dexterity subdomain within the MABC will not be evaluated within this study, as these skills are not included within the categorisation of FMS. These activities are instead related to fine motor skills, so for example, require children to thread beads on a piece of string.

Given the internal consistency of FUNMOVES was lower (.64) than the accepted level PSI (.7) in Chapter 4, the data from all schools (with a wider range of demographics due to purposive sampling) will be re-evaluated.

Finally, hypotheses testing validity will utilise the data from all six schools to evaluate the following:

(i) No significant differences will be found between total FUNMOVES scores for males and females

(ii) Children from low SES will perform significantly worse on FUNMOVES than children from middle and high SES

(iii) White British children will have a significantly higher total FUNMOVES score than South Asian children

5.3.5 Analysis Plan

Agreement between teachers and researchers (inter-rater reliability), the stability of FUNMOVES as a measure across time (test-retest reliability) and how well FUMOVES compares to the MABC (concurrent validity) will be assessed using intra-class correlations (ICC; two-way mixed effects, consistency, multiple raters/measurements). The MABC Aiming & Catching and Balance subscales will be used in analyses, instead of Total Score as the Manual Dexterity subscale does not comprise FMS, rather fine motor skills. Intra-class correlations were chosen as they were the most commonly used statistic in the systematic review for these aspects of reliability and validity (see Chapter 2). ICC evaluates agreement between two quantitative measures for consistency (Müller & Büttner, 1994). For FUNMOVES to be considered to have acceptable inter-rater, test-retest reliability, and concurrent validity, ICCs should be ≥.75, to be classified as ‘good’ or ‘excellent’ (Koo & Li, 2016). This is in alignment with the guidelines used to evaluate studies in the systematic review in Chapter 2.

Bland-Altman plots (Bland & Altman, 1999) will also be used to evaluate inter-rater reliability. Bland-Altmann plots allow an evaluation of mean scoring differences between two individuals (e.g. a teacher and researcher), around 95% agreement limits, to see whether scoring patterns are similar (Bland & Altman, 1999). Using this in combination with ICC will allow a comprehensive overview of scoring differences between researchers and teachers.

PSI will be used to evaluate the internal consistency of FUNMOVES (i.e. through Rasch analysis as was the case in Chapter 4. This will allow the new, untested scoring system for jumping and hopping to also be evaluated for both fit to the Rasch model and to ordered scoring thresholds.

To establish whether FUNMOVES and the MABC identify the same children as struggling with FMS development (predictive validity), logistic regression will be used. Logistic regression allows you to evaluate the extent to which a categorical outcome on one assessment tool (e.g. children identified as below the 15th percentile on FUNMOVES) can predict a child’s categorisation as having difficulties on a different assessment tool (Menard, 2010), such as the MABC, and is therefore ideal for this purpose. A sensitivity and specificity analysis will also be conducted to determine the proportion of true negatives, true positives, false negatives and false positives.

Linear regressions will be used to test whether gender, ethnicity and SES have an impact on FMS ability (as measured by FUNMOVES total score; hypotheses testing validity). Four models will be utilised to evaluate these hypotheses:

Model 1: Independent Variables (IV) – gender, Dependent Variable (DV) – FUNMOVES total score, variables controlled for – age, ethnicity, IMD decile, SEND status, and free school meal status.

Model 2: IV – IMD decile, DV – FUNMOVES total score, variables controlled for – age, gender, ethnicity, SEND status, and free school meal status.

Model 3: IV – free school meal status, DV – FUNMOVES total score, variables controlled for – age, gender, ethnicity, IMD decile, and SEND status.

Model 4: IV – ethnicity, DV – FUNMOVES total score, variables controlled for – age, gender, IMD decile, SEND status, and free school meal status.

5.4 Work Package 2 – Feasibility and Acceptability

5.4.1 Design

The theoretical underpinning of this study was informed by the scaffolding approach (Crotty, 1998), and a diagrammatic representation of this can be seen in Figure 34. Adopting this approach ensures epistemological, philosophical and theoretical perspectives are considered and used to inform the selection of an appropriate methodology. Epistemologically, the research in this work package will be rooted in constructionism which proposes that knowledge is constructed rather than created (Papert & Harel, 1991). It is thought that construction happens when a person interacts within their social environment (i.e. the teachers and their professional environment), which subsequently allows them to construct their own version of reality that is reflective of their experienced truths.

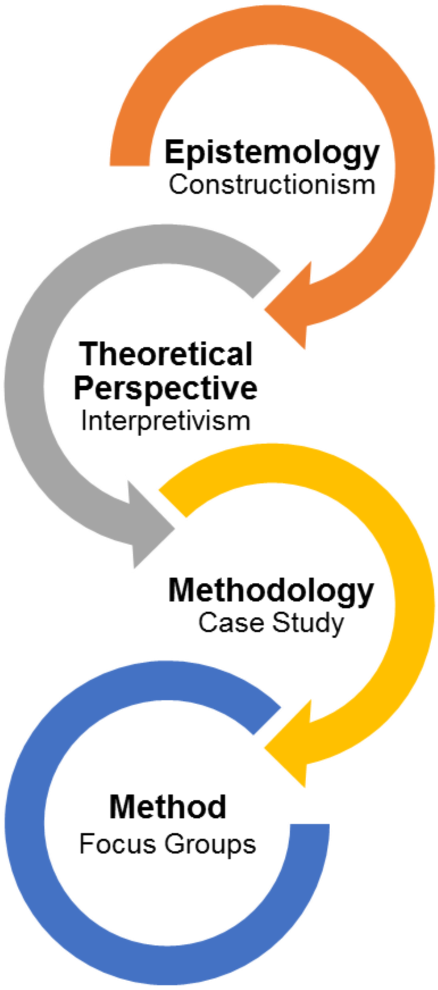


Figure 34 - diagrammatic representation of the scaffolding approach for Work Package 2

Adopting a constructivist approach in this study will allow the researcher to explore the experiences of the teachers as they use FUNMOVES within their workplace. Their interpretation their experiences of using FUNMOVES will inform teachers' perceptions of school-based FMS assessment tools and their evaluation of how useful they are. This will inform the development of their personal "truth" (Crotty, 1998), which will be socially constructed within their professional and workplace culture (i.e. each of the six individual schools). It is accepted that experiences may differ between teachers, however, the researchers want to capture and embrace these conflicting constructions as the aim would be to gather a diversity of experiences. A case study research design will therefore be adopted (at a school level) to help highlight any similarities or differences between the individual teachers in each of the schools thus facilitating cross case analysis between the six schools (Baxter & Jack, 2008).

5.4.2 Participants

Teaching staff will be recruited to focus groups at training sessions, prior to testing commencing in their schools as part of Work Package 1. Researchers will aim to recruit 6-10 teachers from each school for each focus group to optimise group size (Liamputtong, 2011). Where possible, focus groups will consist of at least one teacher or teaching assistant from each year group that helped with the delivery of FUNMOVES, as it is likely that different year groups will pose different challenges. To avoid pre-existing social dynamics influencing the responses of participants, members of the senior leadership team will not be invited to participate (Krueger & Casey, 2014). Focus groups will be conducted in each of the six schools involved in Work Package 1, or until there is saturation in the data, whichever occurs first (Liamputtong, 2011). Saturation occurs when new themes are no longer emerging from focus groups, thus the research is not eliciting any new information.

5.4.3 Measures

To establish the feasibility and acceptability of FUNMOVES, focus groups will be utilised. As was mentioned in Chapter 3, the COM-B model (Michie et al., 2011) allows an understanding of a wide-range of multifaceted factors influencing behaviour(s) through using one model of behaviour change, rather than applying multiple theories or being more selective of theories. Additionally, the COM-B model has matched behaviour change techniques (Behaviour Change Wheel) that propose solutions to increase the likelihood of a behaviour. The questions asked within the focus group will therefore be aligned to the COM-B model, and the prompts for discussion will be based on the associated TDF (Cane et al., 2012) aspects (see Table 38).

Table 38 - Focus Group Discussion Guide

COM-B Aspect	Sub-Component	Question	Prompts
Capability	Psychological	How confident were you that you would be able to assess FMS of your pupils?	• Do you feel like you understand what FMS are and their importance?
	Physical	How prepared did you feel to deliver the assessment tool?	• What were your thoughts on the training session you were given? • What were your thoughts on the teacher manual? • Were you able to demonstrate the activities? • What were your thoughts on the scoring of the tasks/ the score sheet? • Were there any issues you encountered which made implementing the assessment tool more difficult?
Opportunity	Social	How do you think schools could support the use of FUNMOVES?	• What are your thoughts on where FUNMOVES would fit into the curriculum?
	Physical	Do you think it would be feasible	

COM-B Aspect	Sub-Component	Question	Prompts
		to use FUNMOVES to screen FMS in a school setting?	• Would you be able to access support from another member of staff to implement FUNMOVES at the start of the school year? • Does your school have the resources required for you to be able to undertake FUNMOVES? • Do you think that SLT would be supportive of routinely assessing the FMS of pupils at your school?
Motivation	Automatic	What are your thoughts on FUNMOVES?	• Was there anything about FUNMOVES you particularly liked?
	Reflective	Would you use FUNMOVES again, and why?	• Was there anything about FUNMOVES you particularly disliked? • Were there any aspects of

COM-B Aspect	Sub-Component	Question	Prompts
			FUNMOVES you would change? • What were your thought on the feedback given to the school after testing? • Do you think using FUNMOVES was beneficial?

5.4.4 Procedures

Focus groups will be held at each of the schools involved in Work Package 1 and will consist of one teacher from each year group tested. Focus groups will last no longer than an hour, and will be voice recorded and transcribed verbatim to aid analysis. During the focus groups participants will be asked to decide on a pseudonym that they will be referred to throughout in order to ensure anonymity. Participants will be informed that all comments made during focus groups will be confidential, and that they are free to contribute at any time, to encourage active participation (Denzin & Lincoln, 2008). Focus groups will be held in person, in a quiet, place within the school that the teachers work in, to ensure that the participants feel comfortable (Liamputtong, 2011).

A facilitator and a moderator will run the focus groups. The facilitator will ask the questions and encourage discussion around issues as they arise. They will also ensure all participants get a chance to contribute by mitigating dominant voices (Berg et al., 2004). The moderator will take notes on body language and any other non-verbal cues and keep the facilitator to time. Participants in the group will be encouraged to ask any questions about the study to ensure there is a researcher and participant reciprocity in the data collection process. Visual prompts, such as pictures of the activities, and the FUNMOVES manual will be brought to the focus groups to aid memory. Research has found that the use of such prompts helps to ensure the richness (Bukhave & Huniche, 2016) and accuracy (Rose, 2016) of the data collected. This is particularly important, as it is likely that some time may have passed between some teachers' implementation of the assessment tool and the focus groups, in which time, teachers may have forgotten details.

Reflective listening will be used by the researcher throughout the focus groups as it will help the researcher to clarify information ensuring that participants' meanings are not misinterpreted or misconstrued (Charmaz, 2006). It is useful as a way to probe teachers for more information and gather a rich and thick description of their experiences, enabling a complete picture of their opinions to be presented (Bailey, 1982).

Upon completion of focus groups, teachers will be sent transcriptions of their contributions during the session, and will be given the opportunity to change/ amend the transcript to reflect their true feelings to increase the trustworthiness and credibility of the data. This is known as "member checking". Participants will be given two weeks to send back any amendments.

5.4.5 Analysis Plan

NVivo (www.qsrinternational.com/nvivo/) will be used to sort and organise the data using thematic analysis. An experienced qualitative researcher will be used to peer review and moderate a sample of the focus groups and the analysis, thus enhancing credibility and trustworthiness of the study. Thematic analysis allows you to identify and analyse patterns within qualitative data (Joffe, 2011). Thematic analysis was chosen as it is a rigorous and systematic way to engage with data which allows researchers to develop a robust analysis, independent of theoretical frameworks (Willig & Stainton Rogers, 2017). Additionally, thematic analysis can be used to gain group consensus on issues and allows for potential solutions to be highlighted, thus the emphasis is put on themes that are most important to end users (Joffe, 2011). This will be particularly important for establishing ways to improve the feasibility and acceptability of using FUNMOVES within a school setting.

5.5 Research Support

In order to implement the protocol, a minimum of two researchers will be required (i.e. the number needed to score a class using FUNMOVES). It is, however, likely that more researchers will be required to complete the MABC assessments in a timely manner (due to the MABC taking one hour per child). In order to ensure this testing could be completed within the timeframe of the PhD, a number of the 10 Born in Bradford (BiB) interns will be trained to assist with data collection.

5.6 Discussion

It is important to evaluate all aspects of validity and reliability, as Chapter 2 established that many studies have been selective about the psychometric properties measured. The protocol outlined in this chapter would ensure that all psychometric properties outlined by the COSMIN checklist (Mokkink et al., 2010b) that can be quantified (and thus were included in the review in chapter 2) would be evaluated except two: intra-rater reliability and cross-cultural validity.

Intra-rater reliability was not included within this protocol due to the time-pressures that schools face (Routen et al., 2018). This would require teachers and teaching assistants watching the session back (e.g. via video) and re-scoring the children. Although test-retest reliability will have a similar time requirement, unlike test-retest reliability, intra-rater reliability would not be able to be completed with the class present. It would require sessions being filmed and either: (i) the school finding cover for the teacher and teaching assistant so that lessons can continue as usual, or (ii) teaching staff doing this in their own time, after working hours. This was deemed to be an excessive demand to place on teachers on top of focus groups, which may hinder recruitment of schools. Additionally, it is likely that video and in person 'live' assessments would provide dissimilar conditions for scoring. Moreover, with FUNMOVES being used to screen ability, it is unlikely that teachers, in everyday practice, would have the time to review footage of assessments. Thus the research team decided that inter-rater reliability would provide a sufficient indicator for the accuracy of teacher scoring. For cross-cultural validity, as a normative dataset has yet to be established, this would not be possible within the timeframe of this PhD.

For hypotheses testing validity, hypothesis (i) was included as the Rasch analysis (as seen in Chapter 4) found no evidence to support there being sex differences for FUNMOVES across all three studies. This is contrary to previous literature which stipulates gender differences in FMS ability, albeit with differences in regards to whether boys (Adeyemi-Walker et al., 2018; Eyre et al., 2018) or girls (Matarma et al., 2020; Niemistö et al., 2020) are more proficient. It is possible these differences represent sociocultural biases that are present within current assessment tools. For example, boys have been regularly found to be more proficient at object control skills, most frequently kicking (Adeyemi-Walker et al., 2018; Eyre et al., 2018; Kelly et al., 2019). Meanwhile, assessments such as the TGMD (Ulrich, 1985, 2000, 2016) include tasks that require children to kick a football - a skill which is most commonly practiced by boys. As the object control tasks within FUNMOVES will likely be either equally novel (kicking a beanbag) or familiar (throwing a beanbag) to both boys and girls, it is therefore hypothesised these previously reported differences will not occur.

Hypotheses (ii) and (iii) were included as these are commonly found associations within FMS literature (Adeyemi-Walker et al., 2018; Barnett, Lai, et al., 2016; Eyre et al., 2018). Bradford is the ideal setting to test the nature of these relationships as it is ethnically diverse, with roughly equal proportions of White British and South Asian residents (Dickerson et al., 2016) making up , and it is also polarised with regards to SES, with some of the poorest and wealthiest wards in England (Public Health England, 2020a).

Finally, it is critical that research is done with teachers to understand feasibility and acceptability from an end-user viewpoint, to enable modifications to be made (within the remit of what has been accepted by Rasch analysis), to allow universal screening of FMS ability in schools to become a reality.

5.6.1 Strengths and Limitations

Firstly, the research outlined within the protocol in this chapter is proposed to take place in the Bradford district area, to utilise well-established links with BiB, CAER and the DfE's Bradford Opportunity Area to maximise the potential for recruitment to enable testing to occur within the timeframe of this PhD. Bradford is the fifth largest metropolitan district in England (Bradford Council, 2018). It is also one of the most ethnically diverse cities in the UK, including children from South Asian, as well as Central and Eastern European backgrounds (Dickerson et al., 2016). In addition, Bradford is one of the youngest districts, with a third of the population falling under the age of 20 (Bradford Council, 2018). The city encompasses some of the most deprived areas in the UK, with nearly a quarter of children that reside in Bradford live in poverty, and also some of the most wealthy areas (Public Health England, 2020b). Bradford therefore offers a unique opportunity to explore the impact of SES and ethnicity within a city with many young children, and thus will be a great place to explore the hypotheses outlined in Section 5.3.5.

It is, however, important to note that there may potentially be problems for the generalisability of this research, as it utilises a city with such a unique set of demographics. The levels of deprivation, and the proportion of ethnic minorities in Bradford is much greater than the UK average. The latest census data reported that 86% of the population in the UK classified themselves as 'White' and only 7.5% stated they were 'Asian'. Bradford therefore has approximately 32.5% higher rates of people from Asian ethnicity living within the district than the national average (Office for National Statistics, 2011). Additionally, more families in Bradford live in Poverty than the UK average (Public Health England, 2020a). It will therefore be important for future research to establish the validity, reliability, feasibility and acceptability of using FUNMOVES to screen for FMS difficulties in schools outside of the Bradford area, ensuring that a sample which is representative of the demographics within the UK are tested.

Furthermore, to evaluate the feasibility and acceptability of FUNMOVES for use in school-based universal screening programmes of FMS, focus groups were chosen because they are flexible, quicker than interviews and more naturalistic in terms of the conversation elicited and thus can make participants feel more comfortable (Wilkinson, 2004). Additionally, research has shown that interaction between individuals can elicit a lot of data (Morgan, 1996) and that such conversations can lead to ideas being built upon or new ideas being formulated (Morgan, 1996; Wilkinson, 2004). This potential for increased creativity and problem solving will be particularly useful for understanding ways in which the assessment tool could be further modified (Krueger & Casey, 2014) to increase its feasibility and acceptability as a universal screening tool for use within schools. Moreover, focus groups pass more of the control over to the group, which allows them to develop themes which are important to them, rather than priorities set by the researcher. This may help to elicit responses that reveal previously unknown issues (Wilkinson, 2004).

It is, however, important to note that there are a number of potential limitations to using focus groups in this context. Firstly, it has been suggested that all participants in the focus group should be matched on socioeconomic status, gender and ethnicity (Krueger & Casey, 2014). Secondly, it has been postulated that participants of focus groups should not know each other, as this has the potential to bring pre-existing group dynamics into the situation which may make it more difficult for participants to share their opinion (Crabtree et al., 1993). This would not be possible for the focus groups in these studies, due to participants being invited to take part due to their experiences of implementing FUNMOVES. It therefore cannot be guaranteed that teachers within a school all have similar demographics. However, all teachers within the focus group will already know each other and have a working relationship, so there should be a mutual respect within the group. In order to reduce power dynamics impacting upon participants sharing their thoughts, it will however, be important to ensure that separate focus groups are held for members of the Senior Leadership Team (SLT).

Chapter 6
Discussion

6.1 General Summary

This thesis developed an assessment tool that could be utilised for universal screening of FMS ability in a primary school setting. Research has shown that there are a large proportion of children who have ‘below average’ FMS ability, when compared to normative datasets (Bolger et al., 2020). The percentage of children struggling with these skills will likely only have increased due to the lack of movement opportunities afforded to children throughout the COVID-19 pandemic (Pombo et al., 2021; Pombo et al., 2020).

Worryingly, however, despite the importance of FMS for other aspects of development (Brown & Cairney, 2020; De Meester et al., 2020; Jones et al., 2020; Macdonald et al., 2018; Stodden et al., 2008), children in the UK are not routinely screened for such difficulties. Thus, children that would benefit from additional support are being missed. Schools have been identified as the ideal location to host such initiatives (Finch, 2015) as a the majority of children attend school, and those that do spend a large proportion of their week there. Assessing FMS in schools is not a new concept, it is routinely done in Australia (Department of Education Victoria, 2009; Department of Education Western Australia, 2013), however prior to the work in this thesis, there was limited work being done to establish such initiatives in the UK.

This thesis therefore (i) explored what assessment tools were available to measure FMS in school-aged children that could be used for universal screening (ii) evaluated the validity and reliability of these assessment tools (iii) examined what factors would make FMS assessments feasible for use in a school setting and (iv) developed an assessment tool that has strong theoretical and psychometric underpinnings, which is also suitable for use in a universal screening programme of FMS ability within Primary schools.

6.2 Key Findings & Implications

6.2.1 Chapter 2

A systematic review was conducted to understand what observational FMS assessment tools are available to measure the FMS proficiency of school-aged children, what those assessments entail as well as how valid and reliable they were (addressing thesis aims i and ii). The search was conducted in seven online databases, and identified that 24 different assessment tools were being used within the literature for this purpose. Of these assessment tools, over a third (33%, *n*=8) had no studies assessing their validity and/or reliability, and 38% (*n*=9) only had a single study evaluating a limited number of their psychometric properties. What is particularly alarming is that some of these assessment tools (Department of Education Victoria, 2009; Department of Education Western Australia, 2013) are being used for FMS screening in schools, despite the lack of empirical evidence to objectively support their usage in this way. Moreover, research is routinely being conducted that utilises tools that have not had their psychometric properties fully evaluated. Without such comprehensive evaluation of these assessments, it is possible that children struggling with FMS development are being misidentified. Thus, these tools may not serve their intended purpose. Multiple studies were only found for 8 assessment tools, with the most comprehensively evaluated being the MABC (*n*=37 studies), TGMD (*n*=35 studies) and the BOT (*n*=22 studies).

Although this was the first systematic review to evaluate the psychometric properties of assessment tools that have been used to measure specifically FMS in the literature, similar systematic reviews (Griffiths et al., 2018; Hulteen et al., 2020; Scheuer et al., 2019), and narrative reviews (Pill & Harvey, 2019) all identify the MABC, the TGMD and the BOT as being amongst the most widely used, as well as the most valid and reliable assessments currently available for use with children. All of these reviews did, however, have limitations that meant the novel systematic review presented in Chapter 2 was necessary.

Firstly, Hulteen et al. (2018) excluded studies that sampled children with physical and/or cognitive impairments. As children with these difficulties can be found within mainstream schools, it is therefore important that these assessment tools are valid and reliable for use with these populations. The review in Chapter 2 highlighted that some of the more well established assessment tools can be used with these populations, for example the TGMD and the MABC were both found to be suitable for measuring FMS ability in children with visual impairments, with modifications (Bakke et al., 2017; A Brian et al., 2018) as well as children on the Autistic spectrum (Allen et al., 2017; Borremans et al., 2009). The BOT was also found to be a valid and reliable measure for children with intellectual deficits (Wuang & Su, 2009). Prior systematic reviews by Griffiths et al. (2018) and Scheuer et al. (2019) limited their search to assessment tools for educational or clinical settings respectively. These reviews, even when considered in combination, therefore preclude sufficient information to decide on the most appropriate assessment for use in universal screening programmes within schools. Not all observational FMS assessments are covered by their inclusion criteria, as they exclude those which are utilised for research purposes. This was evidenced by the systematic review in this thesis identifying an additional 16 assessment tools not included within these two aforementioned papers (Africa & Kidd, 2013; Canadian Sport for Life, 2013; Department of Education Victoria, 2009; Department of Education Western Australia, 2013; Furtado, 2009; Jiménez-Díaz et al., 2013; Kalaja et al., 2012; Longmuir et al., 2017; Loovis & Ersing, 1979; National Association for Sport and Physical Education, 2010; NSW Department of Education and Training, 2000; Stearns et al., 2019; Sun et al., 2010; Ulrich, 1983; Wessel & Zittel, 1995; Williams et al., 2009). Finally Pill & Harvey (2019) produced a relatively recent narrative review on this topic. However, the results of systematic reviews are known to be less biased due to more rigorous methodologies (Mallett et al., 2012). It is possible that the results of their review were therefore not entirely reflective of the literature within the field.

Whilst none of the four reviews mentioned above cover the entire span of school demographics, or assessment tools that could be used in schools, the results of the systematic review in Chapter 2 confirm similar findings, in that the MABC, the BOT and the TGMD are again identified as the most valid and reliable observational FMS assessment tools for school-aged children. These measures were therefore considered to be the most psychometrically suitable for school-based screening and thus were taken forward for feasibility evaluation in Chapter 3.

6.2.2 Chapter 3

In this chapter, an online questionnaire was used to explore teachers' opinions on hosting FMS assessments in schools, and to understand what the potential barriers and facilitators to universal screening in schools might be (addressing aim iii). The questionnaire was developed utilising two key behaviour change frameworks – the COM-B model (Michie et al., 2011) and the TDF (Cane et al., 2012). This facilitated the pairing of appropriate behaviour change techniques to increase the likelihood of teachers implementing FMS assessments in schools. Over 800 members of teaching staff from 32 different countries responded to the questionnaire (although the majority were based in the UK). Teachers responded, on the whole, very favourably to the proposition of hosting FMS assessments in schools. Over 60% of teachers believed that knowledge about their pupils' FMS ability would improve their teaching, and over 70% would assess the FMS of their class if there was appropriate training and support available for them to do so.

A number of barriers to school-based assessments of FMS were identified, spanning all three aspects of the COM-B model (Michie et al., 2011). For Capability, the main barrier was knowledge about FMS, as 85% of the sample could not correctly identify FMS from a list of wider motor skills. Without such knowledge, it cannot be expected that teachers would be willing or able to assess childhood FMS proficiency. With regards to Opportunity, the main barrier related to the time available within the school day to implement assessment tools. Based on teacher responses, it would suggest that 30-60 minutes is the ideal duration to measure the FMS of a whole class. This is a substantially shorter period of time than the three assessment tools earlier identified in the systematic review would require. For example the MABC (Hendersen et al., 2007; Henderson et al., 1992) takes the maximum duration teachers said was acceptable for class assessment (an hour), to measure the ability of a single child. Finally, workload stress was identified as a barrier within the Motivation component of the COM-B model. This is perhaps unsurprising, given that teaching staff feel under a tremendous amount of time pressure to cover the ‘core’ curriculum alone (Routen et al., 2018) before formal assessments (e.g. SATS).

On the other hand, Social opportunity (or social influences from the TDF) was seen to be a facilitator to school-based FMS assessments. Over 85% of respondents believed that the senior leadership team (SLT) at their school would be supportive if they decided to assess the FMS of their class. With previous research suggesting that SLT support is imperative to the implementation of new initiatives in schools (Taylor et al., 2011), this finding is promising.

Based on the data collected from 853 teachers, six guidelines for assessing the feasibility of school-based FMS assessments were established. This stipulated that any FMS assessment conducted in schools should: (i) take less than ten minutes per child or 30-60 minutes per class to administer; (ii) utilise equipment available in schools or provide necessary equipment; (iii) be implementable in a maximum of five metres squared of space indoors or outdoors; (iv) be implementable by no more than two members of teaching staff; (v) after less than half a day of training; and (vi) be product-oriented in it assesses FMS. Of the three assessment tools identified by the systematic review as being the most psychometrically sound, one does not meet any of these criteria (TGMD), and two only meet one criteria, with the MABC and the BOT both being product-oriented assessments.

The feasibility of FMS assessments in a school environment had previously been explored by two papers (Klingberg et al., 2018; van Rossum et al., 2018).

Klingberg et al. (2018) outlined seven criteria that assessments should meet to be considered feasible for use in schools. However, many of these guidelines were not evidence based, and their formulation does not appear to have been carried out in co-production with teachers – the end user of school-based initiatives. So, it is difficult to ascertain just how practical it would be to follow these guidelines in such settings. Van Rossum et al. (2018) interviewed 39 teachers on their thoughts about assessing FMS in schools. However, all of the teachers interviewed were P.E. specialists. It has previously been reported that there is a lack of P.E. specialists within the UK (Ofsted, 2013), and thus if schools were to be expected to universally screen FMS, it is likely that 'general' class teachers will need to implement these assessments. As these teachers receive less than six hours' worth of training on P.E. during the entire initial teacher training course (Harris et al., 2012) it is unlikely that they will have the same opinions as P.E. specialists on what they would be able to do, due to a skills gap. Thus it is again questionable how representative the sample within Van Rossum et al. (2018) are of the population of most interest here.

The study in Chapter 3 therefore added context to the literature and situated it within a standard school setting to understand feasibility. Considering the guidelines from both of the above studies and the online questionnaire in this thesis, it was evident that no pre-existing observational FMS assessment tools would be feasible for use in school screening programmes. In fact teachers have recently highlighted the need for more school-based FMS measurement tools (van Rossum et al., 2018). Evidence therefore supported the development of a new universal screening tool of FMS, which the remainder of the thesis focused on.

6.2.3 Chapter 4

Utilising the evidence from both chapters 3 and 4, a new assessment tool (FUNMOVES) was developed, addressing aim (iv). FUNMOVES was developed using an iterative process whereby teachers were trained to implement the assessment, they then trialled the activities on their class before Rasch analysis and implementation fidelity results were used to suggest modifications to these activities, before repeating this development cycle. This process was repeated until the Rasch analysis demonstrated strong evidence of structural validity (i.e. the requirements for accurate measurement were met) and major concerns with implementation fidelity were mitigated for.

During this process, over 60 teachers and teaching assistants were trained to use FUNMOVES to evaluate the FMS proficiency of over 800 children. Study 1 found a multi-dimensional measure that did not fit the Rasch model, with disordered thresholds (jumping, hopping non-dominant (ND) and dominant (D) legs, ND foot kicking and walking along the line), local dependency (kicking, D and ND foot; and hopping D and ND legs), and misfitting items (running, ND leg hopping and static balance). There were also issues with the way some activities were implemented. For the static balance activity children were getting multiple opportunities to practice due to the teacher continually demonstrating the activity. Meanwhile, for walking along the line, teachers were setting children off too close together, causing ‘congestion’. Staff were also unclear how much leeway to give children with regards to how close their feet needed to be.

In an attempt to ameliorate these issues, the second iteration of the FUNMOVES battery omitted all non-dominant leg activities, as well as the walking along the line activity. With one of the balance activities removed to reduce the chance of local dependency (ND one leg balance), and feet apart being removed because all children were able to complete this and the second easiest posture, making the inclusion of both redundant, an extra, more challenging, balance was also added in (pick up a beanbag from the floor on one leg). Running scoring was also changed to the number of full lengths (5 metres) run, rather than metres to address disordered thresholds. Finally, teachers were only allowed to demonstrate the activities once, whilst the class were sat down, to remove the opportunity for children to practice.

Study 2 showed a unidimensional measure, with acceptable internal consistency and no local dependency, but which did not fit the Rasch model, had a single mis-fitting item (jumping) and disordered thresholds (jumping, hopping and balance). There were no major issues with the implementation fidelity checklist, with nine of the twelve pairs of teachers complying with all essential criteria. For the remaining classes, the concerns mostly related to teachers missing instructions. In order to resolve the issues highlighted in this study, the training and teacher manual was updated to improve clarity. Additionally, in the third iteration of FUNMOVES, the order of the two most challenging postures within the Static Balance activity (one leg eyes closed and one leg pick up beanbag from the floor) was swapped, as the analysis suggested that one leg eyes closed was more difficult to achieve. The scoring thresholds for jumping and hopping demonstrated that the levels within these activities were never sequentially more difficult, thus a target landing zone was introduced onto each line, which gradually got smaller to increase the precision needed, to see if this task progressively increased the degree of challenge each level within this task presented.

Study 3 trialled these changes within two schools, although the data from one of these schools was deemed to be unreliable due to a lack of time being dedicated to testing sessions, thus this data was removed from the final analysis. Disordered thresholds were found for running (scoring categories 1-5 were not being utilised), jumping and hopping (the middle scoring categories were too similar). However, due to the sole remaining school involved in this study being situated within a high SES area, and children from more advantaged backgrounds are more likely to have better FMS than their more deprived peers (Barnett, Lai, et al., 2016), recommendation to further revise the running scoring was not actioned. Specifically, the working group was concerned that this could limit the utility of this activity in low and middle SES schools. For jumping and hopping, the scoring categories were modified in line with the frequency of achieved scores, and were therefore reduced from six to four scoring categories, which were then classified as 'ordered' when accounting for 95% confidence intervals. This finalised version of FUNMOVES was unidimensional and had no other issues with regards to validity except internal consistency.

The internal consistency was lower than the accepted value within the literature (0.64 vs 0.7) (Fisher, 1992). This wasn't, however considered to be a major concern because Figure 30 demonstrated that the data from this school was skewed towards higher FMS proficiency, which is perhaps unsurprising given the demographics of the school. In the two previous studies, the activities within FUNMOVES were able to measure a wider range of abilities than were present at this school, whereby there were not enough measurement points to differentiate between such a narrow pool of proficiency levels. This will likely not be the case in schools that serve a wider range of SES and ethnicities, and thus this version of FUNMOVES was accepted as the final version. It will, however, be important to test its internal consistency, and the proposed new scoring categories in a range of more diverse schools to verify their utility.

The rigorous process used to develop FUNMOVES allows confidence in its face and content validity. The use of Rasch analysis (a powerful, modern statistical technique) to modify activities, in line with standards for accurate measurement, also allows confidence in its structural validity. Only one other FMS assessment tool has utilised Rasch analysis during its development – P.E. Metrics (National Association for Sport and Physical Education, 2010). However, this group of activities only underwent one round of Rasch analysis, with modifications made based on that single analysis. FUNMOVES is the first FMS assessment tool to undertake such rigorous statistical analysis through multiple rounds of modifications to enhance and ensure structural validity.

There has also been research conducted to ascertain expert opinion (i.e. researchers and trained practitioners) on what school-based assessments of FMS should include (Van Rossum et al., 2021). The guidelines from this paper state that fourteen different skills should be measured. FUNMOVES includes three of these skills as described in their paper (running, hopping forwards, and one leg balance) and three which have slight differences – in FUNMOVES jumping is assessed travelling forwards rather than laterally, throwing is assessed underarm rather than overarm and kicking is completed with a beanbag rather than a ball. In reality, including more skills within FUNMOVES would require a longer duration of assessment, and it is known that there needs to be a trade-off between feasibility and validity/reliability (in this case content validity) in order for school-based initiatives to be implemented consistently and effectively (Koutsouris & Norwich, 2018). Increased duration for assessment will likely make FUNMOVES less acceptable to school teachers, given that the assessment of a class currently takes up to an hour (the upper limit for acceptable class level assessment). It would therefore be inappropriate to increase the number of items.

When considering the items included within FUNMOVES, there are a similar proportion across the three sub-categories of FMS to those within the expert guidelines – with similar emphasis on Locomotor and Object Control skills and less items within Stability. Based on the feasibility guidelines outlined in Chapter 3, which were developed in line with teacher opinion, it suggests FUNMOVES is also feasible for use in schools. It is important to note that this was not a consideration within the expert proposed recommendations by Van Rossum et al. (2021). It will, however, be important to understand the acceptability of FUNMOVES for teachers that have experienced implementing it. Such information would be invaluable in making the process of assessing FMS as easy as possible for non-specialist teachers.

The focus on validity and feasibility throughout the development of FUNMOVES established sound foundations to allow universal screening of FMS ability to occur in schools. Universal screening will have a number of benefits, not only for children, but also for schools involved. Firstly, it gives an opportunity for teaching staff to be upskilled, and receive CPD training. Chapter 3 established that teacher knowledge of FMS was very low. By integrating an assessment of FMS into the schools, teachers will be required to learn about what they are, why they are important and how to assess them. This will empower them with knowledge that will enable a more holistic overview of the development of the children in their class. This will hopefully help teachers to take a more ‘whole-child' approach when dealing with any issues that arise in a given child's development.

Secondly, universal screening has the potential to expedite access to further assessment and intervention because it is well suited to facilitating increased communication and collaboration between healthcare services, families and education, which often exist in very separate silos. The integration and sharing of knowledge from all three areas will enable a more rapid and targeted response to developmental delays, which will ultimately ensure children have the best opportunities to lead a healthy and happy life. Research has previously shown that combining both education and healthcare services can improve the number of children being identified with difficulties, with reduced gender bias (Missiuna et al., 2017). This research, did not, however, screen all children for difficulties. Instead, OTs were placed within schools to visually observe children within a classroom setting, to see whether there were any children struggling to engage with learning, for example with handwriting. If the OTs noticed children with difficulties, these children were then comprehensively assessed using the MABC-2 (Hendersen et al., 2007). Although this method increased the identification of children with motor difficulties, it is problematic that this methodology would likely not help to identify FMS difficulties, due to these skills rarely being exhibited within a typically sedentary classroom setting. Considering the success of even this less comprehensive school identification programme, there is therefore great potential for universally screening FMS ability to yield even wider benefits.

6.3 Future Research

First and foremost, it will be crucial for the protocol outlined in Chapter 5 to be implemented. The studies outlined in this chapter were designed to evaluate the acceptability, validity and reliability of FUNMOVES (addressing aim five). It important that FUNMOVES has (i) acceptability in the eyes of teachers (ii) stable measurement across time and implementers and (iii) scores that are representative of children's true FMS ability level, so that children with difficulties are accurately identified. These are essential pre-conditions before widespread, routine use of FUNMOVES within schools can be considered justifiable.

This work was due to be completed during the timeframe of this PhD, but due to restricted access to schools during the COVID-19 pandemic this was not possible. The pandemic, has however, had a detrimental impact upon children's health and wellbeing. Research has shown that only 27.4% of children in Bradford were meeting physical activity guidelines for MVPA during lockdown

(Bingham et al., 2021) and that FMS proficiency reduced during this time (Pombo et al., 2021). Given the importance of FMS for health and wellbeing (Brown & Cairney, 2020; Cattuzzo et al., 2016; De Meester et al., 2020; Sacko, 2020), it could be argued that screening these skills is now more important than ever, to ensure that children have the best opportunity to catch up with their development.

Specialist P.E. teachers have previously suggested that technology (e.g. electronic tablets) should be utilised for school-based assessments of FMS, and that feedback given to schools needs to be able to feed into lesson plans to improve outcomes for children that are struggling (van Rossum et al., 2018). Whilst in its current form, FUNMOVES does not utilise these two suggestions, there is scope to incorporate both into the measure. There are a number of ways in which technology could be utilised to support the use of FUNMOVES in schools. Firstly, having an app or a website that teachers could use to score children's ability directly into a normative database would not only ensure that the normative data used to calculate performance relative to age was continually updated. Secondly, it would also allow feedback to be given to schools on children's abilities more rapidly. In Chapter 4, teachers filled in scores for children by hand, and then either researchers or administrative staff at the school input these scores into an excel file. Automating this step would save time for both schools, and researchers alike. Similarly, feedback is currently automated through an Excel Macro, transferring such code for use within an online database would enable teachers to receive feedback on their pupils' abilities instantly. It will, however, be imperative that when recruiting for the normative database, that a range of both socioeconomic status and ethnicity are included (Adeyemi-Walker et al., 2018; Barnett, Lai, et al., 2016) to ensure that it is representative of the whole population. Finally, technology could be utilised to widen the scope of FUNMOVES by hosting training sessions online, removing the need for a researcher to travel between schools.

Furthermore, there are a number of important additional research questions that would arise if aspects of FUNMOVES were moved online. Firstly, Chapter 3 established a number of behaviour change techniques that would likely improve the uptake of school-based assessments of FMS, one of which was hosting training in person. This was suggested to ameliorate workload stress, by encouraging a more collaborative environment in schools with regards to FMS. It will therefore be important to establish whether online training would negatively impact upon teachers' perceived abilities to do such assessments within school time. Additionally, research would be needed to evaluate whether online training is as effective as in person training at delivering the key information needed to assess children using FUNMOVES (i.e. are there the same levels of fidelity achieved after online training as after in-person training?). Finally, it would be imperative to understand what information teachers would find useful to be included in automated reports (e.g. whether they would want, individual, class level, and/or school level data, as well as what guidance on their written interpretation is required). This will be particularly important to ensure utility for schools, due to reduced researcher contact with online training and automated reports, as previously, researchers were able to provide additional information to schools on request.

The research detailed above, including further evaluation of psychometric properties, feasibility and acceptability, and digitising aspects of FUNMOVES has been presented to Sport England and the London Marathon Charitable Trust, and they are providing funding for a post-doc position to enable further development as well as to broaden FUNMOVES to include wider aspects of physical literacy.

With regards to providing teachers with feedback, van Rossum et al. (2018) found that teachers would like FMS assessment tools to feedback on ways to facilitate improvements in FMS ability within the school. Whilst FUNMOVES does not currently do this, there is an aligned intervention programme presently being developed within Bradford, which could be incorporated (Towards Healthy Education; Accelerated Learning of Playground Skills; The Alps) to facilitate such feedback. The Alps was developed by researchers at the University of Leeds in an attempt to mitigate the need for over-stretched NHS services to be heavily involved in supporting children, families and schools (Finch, 2015) in efforts to reduce identified FMS difficulties.

The Alps is a teacher-led intervention, in which schools are given a manual that outlines activities, how to implement them and the frequency that they should be practiced in order to help advance children’s FMS. The activities within the manual are based on evidence-based activities found within a systematic review of high quality randomised controlled trials (Preston et al., 2017) which were proven to be the most effective at improving FMS in clinical settings. The manual was co-developed with teachers and teaching assistants to ensure clarity and school staff have been observed to ensure that what is written translates to accurate implementation of the activities. There is the opportunity to align The Alps with FUNMOVES feedback, by integrating a ‘prescription’ of activities for children that are identified as struggling using FUNMOVES, tailored to their specific needs. Activities could also be suggested on a class level to address the, on average, least well performed aspects of FMS within the group. This will empower schools and teachers further, to not only allow them to identify difficulties but also begin to resolve them. Additionally, it will enable some of the burden to be reduced on over-stretched NHS services, potentially enabling quicker appointment times for the children who need more specialist help with motor difficulties. However, the efficacy of teacher implementation of these physiotherapy exercises has yet to be tested. It will be crucial to ensure that these activities have utility in school settings, before The Alps can be integrated into FUNMOVES feedback.

In addition to the research outlined above, it would be advantageous to explore whether FMS ability as scored by FUNMOVES is associated with other aspects of childhood development. By capitalising on the work that is already being done by the Bradford Institute for Health Research to link healthcare and education data, and working in collaboration with the Born in Bradford (BiB) longitudinal cohort study, data collection for FUNMOVES across Bradford would enable such associations to be evaluated. Firstly there is a lack of research on the influence of early life factors on FMS development. Within the BiB 1000 cohort (a nested sub cohort, comprising 1700+ mothers) data was collected on the home environment, from 0 to 3 years of age, which may influence a child's opportunity to develop FMS. For example, when the children were two and three years old questionnaires asked mothers about (i) their own physical activity behaviours (ii) their child's physical activity behaviours (iii) access to active toys, such as trampolines, climbing frames, balls and bikes, (iv) the time their child spends playing actively, and (v) the time their child spends in indoor and outdoor play areas. Testing for associations between these early learning opportunities and later FMS ability (as measured by FUNMOVES) would enable insights into the role the home environment plays in physical activity behaviours. One study has previously looked at similar associations in an Australian sample (Barnett, Hnatiuk, et al., 2019), but there has yet to be such research within the UK.

Exploring relationships between FMS and other aspects childhood development that have previously been evaluated within the literature would also be beneficial (see Chapter 1), using both cross sectional, and longitudinal analyses. For example evaluating the relationship between FMS (as measured by FUNMOVES) and academic attainment, socioemotional development, physical activity, physical literacy and health as well as exploring whether biological, home environment, social and cultural factors act as moderators and mediators for these relationships.

Finally, considering that the purpose of FUNMOVES is to identify children struggling with FMS development, it would be interesting to evaluate the clinical significance of the tool. As assessments for motor skill difficulties are currently based within the NHS, it would be essential to work collaboratively with healthcare professionals (e.g. occupational therapists and physiotherapists) to evaluate the utility of FUNMOVES for use by these professional groups in their practice. For example, it could be interesting to evaluate how teacher identification of children with FMS difficulties (using FUNMOVES) compares to occupational therapists'/ physiotherapists' opinion of difficulties and whether FUNMOVES is suitable for assessing the fundamental movement skills of children who have special educational needs and disabilities.

6.4 Conclusion

To conclude, this thesis developed a universal screening tool of FMS with sound theoretical and psychometric underpinnings that is feasible for use in schools. The extensive groundwork done in advance of developing FUNMOVES, in particular, enables enhanced confidence in its theoretical underpinnings and its feasibility. A systematic review evaluating pre-existing FMS assessment tools and their validity and reliability was conducted. The results of this review showed that three assessment tools had sufficient evidence to support their use in schools – the MABC, the BOT and the TGMD. Feasibility in a school setting was then explored, utilising an online questionnaire to understand teacher opinions of FMS assessments in schools, as well as barriers and facilitators to such initiatives. Results highlighted that none of the pre-existing assessment tools that had strong psychometric properties would be feasible for use in schools. From this questionnaire guidelines were set for what FMS assessments in schools should entail in order to be feasible. These were then used to underpin the development of FUNMOVES. Utilising Rasch analysis, through a rigorous and iterative process of development, enabled confidence in its structural validity.

As FUNMOVES has sound theoretical and psychometric underpinnings and is feasible for use in schools, it may provide a solution to the inequalities that are present within the healthcare system which hosts motor skill assessments currently within the UK. There is great potential for universal screening of FMS ability in schools, including increased teacher awareness, expedited time to assessment and intervention, as well as increased communication and collaboration between healthcare, education and families. It is, however, clear that more research needs to be undertaken before FUNMOVES can be used within this context.

References

Aadland, E., Andersen, L. B., Migueles, J. H., Ortega, F. B., & Kvalheim, O. M. (2020). Interpretation of associations between the accelerometry physical activity spectrum and cardiometabolic health and locomotor skills in two cohorts of children using raw, normalized, log-transformed, or compositional data. *Journal of Sports Sciences, 38*(23), 2708-2719.

Adam, C., Klissouras, V., & Ravasollo, M. (1988). *Eurofit: Handbook for the Eurofit Tests of Physical Fitness*. Council of Europe, Committee for the Development of Sport.

Adeyemi-Walker, L. J., Duncan, M., Tallis, J., & Eyre, E. (2018). Fundamental motor skills of children in deprived areas of england: A focus on age, gender and ethnicity. *Children, 5*(8), 110.

Africa, E. K., & Kidd, M. (2013). Reliability of the teen risk screen: a movement skill screening checklist for teachers. *South African Journal for Research in Sport, Physical Education and Recreation, 35*(1), 1-10.

Allen, K., Bredero, B., Van Damme, T., Ulrich, D., & Simons, J. (2017). Test of gross motor development-3 (TGMD-3) with the use of visual supports for children with autism spectrum disorder: validity and reliability. *Journal of autism and developmental disorders, 47*(3), 813-833. https://link.springer.com/article/10.1007/s10803-016-3005-0

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)*. American Psychiatric Pub.

Anastasi, A., & Urbina, S. (1997). *Psychological Testing.* Prentice Hall.

Andrich, D. (1985). An elaboration of Guttman scaling with Rasch models for measurement. *Sociological methodology, 15*, 33-80.

Avery, L. M., Russell, D. J., Raina, P. S., Walter, S. D., & Rosenbaum, P. L. (2003). Rasch analysis of the Gross Motor Function Measure: validating the assumptions of the Rasch model to create an interval-level measure. *Archives of physical medicine and rehabilitation, 84*(5), 697-705. https://www.archives-pmr.org/article/S0003-9993(02)04896-7/pdf

Bailey, K. D. (1982). *Methods of Social Research.* Macmillan Publishing Co.

Baker, E. H. (2014). Socioeconomic status, definition. *The Wiley Blackwell encyclopedia of health, illness, behavior, & society*, 2210-2214.

Bakke, H. A., Sarinho, S. W., & Cattuzzo, M. T. (2017). Adaptation of the MABC-2 Test (Age Band 2) for children with low vision. *Research in Developmental Disabilities, 71*, 120-129. https://www.sciencedirect.com/science/article/abs/pii/S0891422217302482?via%3Dihub

Bardid, F., Huyben, F., Lenoir, M., Seghers, J., De Martelaer, K., Goodway, J. D., & Deconinck, F. J. (2016). Assessing fundamental motor skills in Belgian children aged 3–8 years highlights differences to US reference sample. *Acta Paediatrica, 105*(6), e281-e290. https://onlinelibrary.wiley.com/doi/abs/10.1111/apa.13380

Bardid, F., Utesch, T., & Lenoir, M. (2019). Investigating the construct of motor competence in middle childhood using the BOT-2 Short Form: An item response theory perspective. *Scandinavian journal of medicine & science in sports, 29*(12), 1980-1987.

Bardid, F., Vannozzi, G., Logan, S. W., Hardy, L. L., & Barnett, L. M. (2019). A hitchhiker's guide to assessing young people's motor competence: Deciding what method to use. *Journal of Science & Medicine in Sport, 22*(3), 311-318.

Barnett, A. L., Hill, E. L., Kirby, A., & Sugden, D. A. (2015). Adaptation and Extension of the European Recommendations (EACD) on Developmental Coordination Disorder (DCD) for the UK context. *Physical & occupational therapy in pediatrics, 35*(2), 103-115.

Barnett, L. M., Hnatiuk, J. A., Salmon, J., & Hesketh, K. D. (2019). Modifiable factors which predict children's gross motor competence: a prospective cohort study. *International Journal of Behavioural Nutrition and Physical Activity, 16*(1), 129.

Barnett, L. M., Lai, S. K., Veldman, S. L., Hardy, L. L., Cliff, D. P., Morgan, P. J., Zask, A., Lubans, D. R., Shultz, S. P., & Ridgers, N. D. (2016). Correlates of gross motor competence in children and adolescents: a systematic review and meta-analysis. *Sports Medicine, 46*(11), 1663-1688.

Barnett, L. M., Minto, C., Lander, N., & Hardy, L. L. (2014). Interrater reliability assessment using the Test of Gross Motor Development-2. *Journal of science and medicine in sport, 17*(6), 667-670. https://www.jsams.org/article/S1440-2440(13)00230-2/fulltext

Barnett, L. M., Stodden, D., Cohen, K. E., Smith, J. J., Lubans, D. R., Lenoir, M., Iivonen, S., Miller, A. D., Laukkanen, A., & Dudley, D. (2016). Fundamental movement skills: An important focus. *Journal of Teaching in Physical Education, 35*(3), 219-225.

Barnett, L. M., Telford, R. M., Strugnell, C., Rudd, J., Olive, L. S., & Telford, R. D. (2019). Impact of cultural background on fundamental movement skill and its correlates. *Journal of Sports Sciences, 37*(5), 492-499.

Barnett, L. M., van Beurden, E., Morgan, P. J., Brooks, L. O., & Beard, J. R. (2010). Gender differences in motor skill proficiency from childhood to adolescence: A longitudinal study. *Research quarterly for exercise & sports, 81*(2), 162-170.

Barnett, L. M., Webster, E. K., Hulteen, R. M., De Meester, A., Valentini, N. C., Lenoir, M., Pesce, C., Getchell, N., Lopes, V. P., Robinson, L. E., Brian, A., & Rodrigues, L. P. (2021, 2021/08/31). Through the Looking Glass: A Systematic Review of Longitudinal Evidence, Providing New Insight for Motor Competence and Health. *Sports Medicine*. https://doi.org/10.1007/s40279-021-01516-8

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The qualitative report, 13*(4), 544-559.

Becker, R., Möser, S., & Glauser, D. (2019). Cash vs. vouchers vs. gifts in web surveys of a mature panel study—Main effects in a long-term incentives experiment across three panel waves. *Social Science Research, 81*, 221-234.

Behan, S., Belton, S., Peers, C., O'Connor, N. E., & Issartel, J. (2019). Moving Well-Being Well: Investigating the maturation of fundamental movement skill proficiency across sex in Irish children aged five to twelve. *Journal of Sports Sciences, 37*(22), 2604-2612.

Behan, S., Belton, S., Peers, C., O'Connor, N. E., & Issartel, J. J. E. J. o. S. S. (2020). Exploring the relationships between fundamental movement skills and health related fitness components in children. 1-23.

Berg, B. L., Lune, H., & Lune, H. (2004). *Qualitative research methods for the social sciences* (Vol. 5). Pearson

Bevans, K., Fitzpatrick, L.-A., Sanchez, B., & Forrest, C. B. (2010). Individual and instructional determinants of student engagement in physical education. *Journal of Teaching in Physical Education, 29*(4), 399-416.

Bingham, D. D., Daly-Smith, A., Hall, J., Seims, A., Dogra, S. A., Fairclough, S. J., Ajebon, M., Kelly, B., Hou, B., Shire, K. A., Crossley, K. L., Mon-Williams, M., Wright, J., Pickett, K. E., McEachan, R. R., Dickerson, J., & Barber, S. (2021). Covid-19 lockdown: Ethnic differences in children's self-reported physical activity and the importance of leaving the home environment. A longitudinal and cross-sectional. *International Journal of*

Behavioural Nutrition & Physical Activity, 18. https://doi.org/https://doi.org/10.1186/s12966-021-01183-y

Bland, J. M., & Altman, D. G. (1999). Measuring agreement in method comparison studies. *Statistical methods in medical research, 8*(2), 135-160.

Blank, R., Barnett, A. L., Cairney, J., Green, D., Kirby, A., Polatajko, H., Rosenblum, S., Smits-Engelsman, B., Sugden, D., & Wilson, P. (2019). International clinical practice recommendations on the definition, diagnosis, assessment, intervention, and psychosocial aspects of developmental coordination disorder. *Developmental medicine and child neurology, 61*(3), 242-285.

Blank, R., Smits-Engelsman, B., Polatajko, H., & Wilson, P. (2012). European Academy for Childhood Disability (EACD): Recommendations on the definition, diagnosis and intervention of developmental coordination disorder (long version). *Developmental medicine and child neurology, 54*(1), 54-93.

Bolger, L. E., Bolger, L. A., O'Neill, C., Coughlan, E., O'Brien, W., Lacey, S., Burns, C., & Bardid, F. (2020). Global levels of fundamental motor skills in children: A systematic review. *Journal of Sports Sciences*, 1-37.

Boone, W. J. (2016). Rasch Analysis for Instrument Development: Why, When, and How? *CBE Life Sciences Education, 15*(4), 1-7.

Boone, W. J., Staver, J., & Yale, M. (2014). *Rasch Analysis in the Human Sciences*. Springer.

Booth, M., Okely, A., Denney-Wilson, E., Hardy, L., Yang, B., & Dobbins, T. (2006). *NSW schools physical activity and nutrition survey (SPANS) 2004: Summary report*.

Borremans, E., Rintala, P., & McCubbin, J. A. (2009). Motor Skills of Young Adults with Asperger Syndrome: A comparative Study. *European Journal of Adapted Physical Activity, 2*(1), 21-33.

Boulianne, S. (2013). Examining the gender effects of different incentive amounts in a web survey. *Field Methods, 25*(1), 91-104.

Bradford Council. (2018). *City of Bradford Metropolitan District Council: Bradford District population update*.

Brian, A., Bardid, F., Barnett, L. M., Deconinck, F. J., Lenoir, M., & Goodway, J. D. (2018). Actual and perceived motor competence levels of Belgian and

United States preschool children. *Journal of Motor Learning and Development, 6*(S2), S320-S336.

Brian, A., Goodway, J. D., Logan, J. A., & Sutherland, S. (2017). SKIPing with Head Start teachers: Influence of T-SKIP on object-control skills. *Research quarterly for exercise and sport, 88*(4), 479-491. https://doi.org/https://doi.org/10.1080/02701367.2017.1375077

Brian, A., Pennell, A., Taunton, S., Starrett, A., Howard-Shaughnessy, C., Goodway, J. D., Wadsworth, D., Rudisill, M., & Stodden, D. (2019). Motor competence levels and developmental delay in early childhood: A multicenter cross-sectional study conducted in the USA. *Sports Medicine, 49*(10), 1609-1618.

Brian, A., Taunton, S., Lieberman, L. J., Haibach-Beach, P., Foley, J., & Santarossa, S. (2018). Psychometric Properties of the Test of Gross Motor Development-3 for Children With Visual Impairments. *Adapted physical activity quarterly, 35*(2), 145-158. https://journals.humankinetics.com/view/journals/apaq/35/2/article-p145.xml

Brown, D. M., & Cairney, J. (2020). The synergistic effect of poor motor coordination, gender and age on self-concept in children: A longitudinal analysis. *Research in Developmental Disabilities, 98*, 103576.

Brown, T. (2019a). Structural Validity of the Bruininks-Oseretsky Test of Motor Proficiency–Second Edition (BOT-2) Subscales and Composite Scales. *Journal of Occupational Therapy, Schools, & Early Intervention, 12*(3), 323-353.

Brown, T. (2019b). Structural validity of the Bruininks-Oseretsky test of motor proficiency–second edition brief form (BOT-2-BF). *Research in Developmental Disabilities, 85*, 92-103. https://www.sciencedirect.com/science/article/abs/pii/S0891422218302385?via%3Dihub

Brown, T., & Lane, H. (2014). Comparing a parent-report and a performance-based measure of children's motor skill abilities: are they associated? *Occupational Therapy in Health Care, 28*(4), 371-381.

Bruininks, R. (1978). *Bruininks-Oseretsky test of motor proficiency*. American Guidance Service

Bruininks, R., & Bruininks, B. (2005). *Bruininks-Oseretsky Test of Motor Proficiency (2nd Edition) Manual*. AGS Publishing.

Bukhave, E. B., & Huniche, L. (2016). Photo-interviewing to explore everyday occupation: Benefits and issues. *Journal of Occupational Science, 23*(1), 96-107.

Burns, R. D., Bai, Y., Byun, W., Colotti, T. E., Pfledderer, C. D., Kwon, S., & Brusseau, T. A. (2020, 2020/07/09/). Bidirectional relationships of physical activity and gross motor skills before and after summer break: Application of a cross-lagged panel model. *Journal of sport and health science, 00*, 1-9. https://doi.org/https://doi.org/10.1016/j.jshs.2020.07.001

Bushnell, E. W. (1985). The decline of visually guided reaching during infancy. *Infant Behaviour & Development, 8*(2), 139-155.

Cairney, J., Hay, J., Veldhuizen, S., Missiuna, C., & Faught, B. (2009). Comparing probable case identification of developmental coordination disorder using the short form of the Bruininks-Oseretsky Test of Motor Proficiency and the Movement ABC. *Child: care, health and development, 35*(3), 402-408. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2214.2009.00957.x

Cairney, J., Veldhuizen, S., Graham, J. D., Rodriguez, C., Bedard, C., Bremer, E., & Kriellaars, D. (2018). A Construct Validation Study of PLAYfun. *Medicine and science in sports and exercise, 50*(4), 855.

Canadian Sport for Life. (2013). *Physical Literacy Assessment for Youth Basic*. Canadian Sport Institute - Pacific. http://physicalliteracy.ca/wp-content/uploads/2016/08/PLAYbasic_workbook.pdf

Cane, J., O'Connor, D., & Michie, S. (2012). Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implementation science, 7*(1), 37.

Cano-Cappellacci, M., Leyton, F. A., & Carreño, J. D. (2016). Content validity and reliability of test of gross motor development in Chilean children. *Revista de saude publica, 49*, 97.

Capio, C. M., & Eguia, K. F. (2020). Movement skills, perception, and physical activity of young children: a mediation analysis. *Pediatrics International, in press*.

Capio, C. M., Eguia, K. F., & Simons, J. (2016). Test of gross motor development-2 for Filipino children with intellectual disability: validity and reliability. *Journal of Sports Sciences, 34*(1), 10-17.

Capio, C. M., Sit, C. H., & Abernethy, B. (2011). Fundamental movement skills testing in children with cerebral palsy. *Disability and rehabilitation, 33*(25-26), 2519-2528.

Carmines, E. G., & Zeller, R. A. (1979). *Reliability and validity assessment* (Vol. 17). Sage publications.

Casler, K., Bickel, L., & Hackett, E. (2013). Separate but equal? A comparison of participants and data gathered via Amazon's MTurk, social media, and face-to-face behavioral testing. *Computers in human behavior, 29*(6), 2156-2160. https://doi.org/https://doi.org/10.1016/j.chb.2013.05.009

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Reports, 100*(2), 126-131.

Cattuzzo, M. T., dos Santos Henrique, R., Ré, A. H. N., de Oliveira, I. S., Melo, B. M., de Sousa Moura, M., de Araújo, R. C., & Stodden, D. (2016). Motor competence and health related physical fitness in youth: A systematic review. *Journal of Science & Medicine in Sport, 19*(2), 123-129.

Chambers, M. E., & Sugden, D. A. (2002). The Identification and Assessment of Young Children with Movement Difficulties. *International Journal of Early Years Education, 10*(3), 157-176.

Chan, Y. (2003). Biostatistics 104: correlational analysis. *Singapore Med J, 44*(12), 614-619.

Chang, M., & Gu, X. (2018). The role of executive function in linking fundamental motor skills and reading proficiency in socioeconomically disadvantaged kindergarteners. *Learning & Individual Differences, 61*, 250-255.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. sage.

Chen, W.-H., & Thissen, D. (1997). Local dependence indexes for item pairs using item response theory. *Journal of Educational and Behavioral Statistics, 22*(3), 265-289.

Chien, C.-W., & Bond, T. G. (2009). Measurement properties of fine motor scale of Peabody developmental motor scales-: A Rasch analysis. *American Journal of Physical Medicine & Rehabilitation, 88*(5), 376-386.

Chow, S. M., Chan, L.-L., Chan, C. P., & Lau, C. H. (2002). Reliability of the experimental version of the Movement ABC. *British Journal of Therapy and Rehabilitation, 9*(10), 404-407.

Clark, C. C. T., Bisi, M. C., Duncan, M. J., & Stagni, R. (2021). Technology-based methods for the assessment of fine and gross motor skill in children: A systematic overview of available solutions and future steps for effective in-field use. *Journal of Sports Sciences, 39*(11), 1236-1276.

Clark, H., Royal, P., Manners, L., Baston-Pitt, L., Revel, E., Leech, G., Davies, C., Mackay, E., Wyllie, E., Nash, A., Smith, S., Franks, S., Broadbent, C., Albon, D., Coleman, N., Lee, D., Platt, G., Peckham, K., & Randall, V. (2017). *Physical Activity in Early Childhood*. APPG.

Clark, J. E. (1994). *Motor development* (Vol. 3). Academic Press.

Clark, J. E., & Metcalfe, J. S. (2002). The mountain of motor development: A metaphor. *Motor Development: Research & Reviews, 2*(163-190), 183-202.

Cohen, K. E., Morgan, P. J., Plotnikoff, R. C., Callister, R., & Lubans, D. R. (2014). Fundamental movement skills and physical activity among children living in low-income communities: a cross-sectional study. *International Journal of Behavioural Nutrition and Physical Activity, 11*(1), 49.

Cook, C. J., Howard, S. J., Scerif, G., Twine, R., Kahn, K., Norris, S. A., & Draper, C. E. (2019). Associations of physical activity and gross motor skills with executive function in preschool children from low-income South African settings. *Developmental Science, 22*(5), e12820.

Cook, G., Burton, L., & Hoogenboom, B. (2006a). Pre-participation screening: the use of fundamental movements as an assessment of function-part 1. *North American journal of sports physical therapy: NAJSPT, 1*(2), 62-72. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2953313/pdf/najspt-01-062.pdf

Cook, G., Burton, L., & Hoogenboom, B. (2006b). Pre-participation screening: the use of fundamental movements as an assessment of function-part 2. *North American journal of sports physical therapy: NAJSPT, 1*(3), 132-139.

Cookson, R., Propper, C., Asaria, M., & Raine, R. (2016). Socio-economic inequalities in health care in England. *Fiscal Studies, 37*(3-4), 371-403.

Cools, W., De Martelaer, K., Samaey, C., & Andries, C. (2011). Fundamental movement skill performance of preschool children in relation to family context. *Journal of Sports Sciences, 29*(7), 649-660.

Cowen, P. S. (2001). Effectiveness of a parent education intervention for at-risk families. *Journal for Specialists in Pediatric Nursing, 6*(2), 73-82.

Crabtree, B. F., Yanoshik, M., Miller, W., & O'Connor, P. (1993). Successful focus groups: advancing the state of the art. *Selecting individual or group interviews*, 137-152.

Crawford, S. G., Wilson, B. N., & Dewey, D. (2001). Identifying developmental coordination disorder: consistency between tests. *Physical & occupational therapy in pediatrics, 20*(2-3), 29-50.

Croce, R. V., Horvat, M., & McCarthy, E. (2001). Reliability and concurrent validity of the movement assessment battery for children. *Perceptual and motor skills, 93*(1), 275-280.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. Sage.

Culmer, P. R., Levesley, M. C., Mon-Williams, M., & Williams, J. H. (2009). A new tool for assessing human movement: the kinematic assessment tool. *Journal of Neuroscience Methods, 184*(1), 184-192.

D'Hondt, E., Deforche, B., Gentier, I., Verstuyf, J., Vaeyens, R., De Bourdeaudhuij, I., Philippaerts, R., & Lenoir, M. (2014). A longitudinal study of gross motor coordination and weight status in children. *Obesity, 22*(6), 1505-1511.

da Rocha Queiroz, D., Guimarães, T. G. M., Campos, C. M. C., Feitoza, A. H. P., dos Santos Henrique, R., dos Santos, M. A. M., & Cattuzzo, M. T. (2020). Effect of school type and family income on motor competence changes in pre-school children: a repeated cross sectional study. *Journal of Physical Education, 31*(1).

Daly-Smith, A., Quarmby, T., Archbold, V. S., Corrigan, N., Wilson, D., Resaland, G. K., Bartholomew, J. B., Singh, A., Tjomsland, H. E., & Sherar, L. B. (2020). Using a multi-stakeholder experience-based design process to co-develop the Creating Active Schools Framework. *International Journal of Behavioural Nutrition & Physical Activity, 17*(1). https://doi.org/https://doi.org/10.1186/s12966-020-0917-z

Darsaklis, V., Snider, L. M., Majnemer, A., & Mazer, B. (2013). Assessments used to diagnose developmental coordination disorder: Do their underlying constructs match the diagnostic criteria? *Physical & occupational therapy in pediatrics, 33*(2), 186-198.

De Meester, A., Barnett, L. M., Brian, A., Bowe, S. J., Jiménez-Díaz, J., Van Duyse, F., Irwin, J. M., Stodden, D. F., D'Hondt, E., & Lenoir, M. (2020). The Relationship Between Actual and Perceived Motor Competence in Children, Adolescents and Young Adults: A Systematic Review and Meta-analysis. *Sports Medicine, 50*(11), 1-49.

de Waal, E. (2019). Fundamental movement skills and academic performance of 5-to 6-year-old preschoolers. *Early Childhood Education Journal, 47*(4), 455-464.

De Waal, E., & Pienaar, A. E. (2020). Influences of early motor proficiency and socioeconomic status on the academic achievement of primary school learners: the NW-CHILD study. *Early Childhood Education Journal*, 1-12.

Denzin, N. K., & Lincoln, Y. S. (2008). *Collecting and interpreting qualitative materials* (Vol. 3). Sage.

Department for Digital Culture Media & Sport. (2015). *Sporting Future: A New Strategy for an Active Nation*. H. Government. https://www.gov.uk/government/publications/sportingfuture-a-new-strategy-for-an-active-nation

Department For Education. (2013). *Physical Education Programmes of Study: Key Stages 1 and 2, The National Curriculum.* H. Government.

Department For Education. (2014). *Early year's foundation stage*. H. Government. https://www.gov.uk/government/publications/early-years-foundation-stage-framework--2

Department for Education. (2019a). *Early years foundation stage profile results in England, 2019*. H. Government. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/839934/EYFSP_2019_Main_Text_Oct.pdf

Department For Education. (2019b). *PE and sport premium for primary schools*. HM Government https://www.gov.uk/guidance/pe-and-sport-premium-for-primary-schools

Department for Education. (2020). *Early years foundation stage profile 2021 handbook*. H. Government. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/942421/EYFSP_Handbook_2021.pdf

Department for Education, Department for Digital Culture Media and Sport, & Department for Health and Social Care. (2019). *School Sport and Activity Action Plan*. H. Government. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/848082/School_sport_and_activity_action_plan.pdf

Department of Education Victoria. (2009). *Fundamental Motor Skills: A Manual For Classroom Teachers*. Department of Education Victoria.

Department of Education Western Australia. (2013). *Fundamental movement skills: Book 2 – The tools for learning, teaching and assessment*. http://det.wa.edu.au/stepsresources/detcms/navigation/fundamental-movement-skills/

Department of Health and Social Care. (2019). *UK Chief Medical Officers' Physical Activity Guidelines* G. o. t. U. Kingdom. https://www.gov.uk/government/publications/physical-activity-guidelines-uk-chief-medical-officers-report

Diamond, A. (2000). Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child Development, 71*(1), 44-56.

Diamond, A. (2007). Interrelated and interdependent. *Developmental Science, 10*(1), 152-158.

Dickerson, J., Bird, P. K., McEachan, R. R., Pickett, K. E., Waiblinger, D., Uphoff, E., Mason, D., Bryant, M., Bywater, T., & Bowyer-Crane, C. (2016). Born in Bradford’s Better Start: an experimental birth cohort study to evaluate the impact of early life interventions. *BMC public health, 16*(1), 711.

Dobell, A., Pringle, A., Faghy, M. A., & Roscoe, C. M. (2021). Educators Perspectives on the Value of Physical Education, Physical Activity and Fundamental Movement Skills for Early Years Foundation Stage Children in England. *Children, 8*.

dos Santos, J. O. L., Formiga, N. S., de Melo, G. F., da Silva Ramalho, M. H., & Cardoso, F. L. (2017). Factorial Structure Validation of the Movement Assessment Battery for Children in School-Age Children Between 8 and 10 Years Old. *Paidéia (Ribeirão Preto), 27*(68), 348-355.

Draper, C. E., Tomaz, S. A., Jones, R. A., Hinkley, T., Twine, R., Kahn, K., & Norris, S. A. (2019). Cross-sectional associations of physical activity and gross motor proficiency with adiposity in South African children of pre-school age. *Public Health Nutrition, 22*(4), 614-623.

Drost, E. A. (2011). Validity and reliability in social science research. *Educational Research & Perspectives, 38*(1), 105-124.

Duncan, M., Hall, C., Eyre, E., Barnett, L., & James, R. (2021). Pre-schoolers fundamental movement skills predict BMI, physical activity and sedentary behaviour: A longitudinal study. *Scandinavian journal of medicine & science in sports, 31*, 8-14.

Duncan, M. J., Dobell, A., Noon, M., Clark, C. C., Roscoe, C. M., Faghy, M. A., Stodden, D., Sacko, R., & Eyre, E. L. (2020). Calibration and cross-validation of accelerometery for estimating movement skills in children aged 8–12 years. *Sensors, 20*(10), 2776.

Duncan, M. J., Roscoe, C. M., Faghy, M., Tallis, J., & Eyre, E. L. (2019). Estimating physical activity in children aged 8–11 years using accelerometry: Contributions from fundamental movement skills and different accelerometer placements. *Frontiers in Physiology, 10*, 242.

Duncan, M. J., Roscoe, C. M., Noon, M., Clark, C. C., O'Brien, W., & Eyre, E. L. (2020). Run, jump, throw and catch: How proficient are children attending English schools at the fundamental motor skills identified as key within the school curriculum? *European Physical Education Review, 26*(4), 814-826.

Duncan, P. W., Bode, R. K., Lai, S. M., & Perera, S. (2003). Rasch analysis of a new stroke-specific outcome scale: the Stroke Impact Scale. *Archives of physical medicine and rehabilitation, 84*(7), 950-963. https://www.archives-pmr.org/article/S0003-9993(03)00035-2/pdf

Dunford, C., Owen, C., & Kelly, J. (2010). Occupational therapy with children and young people: A perspective from the United Kingdom. *Journal of Occupational Therapy, Schools & Early Intervention, 3*(2), 187-196.

Dunford, C., & Richards, S. (2003). *'Doubly disadvantaged': report of a survey on waiting lists and waiting times for occupational therapy services for children with developmental coordination disorder*.

Ellinoudis, T., Kourtessis, T., Kiparissis, M., Kampas, A., & Mavromatis, G. (2008). Movement Assessment Battery for Children (MABC): Measuring the construct validity for Greece in a sample of elementary school aged children. *International Journal of Health Science, 1*(2), 56-60.

Erwin, H. E., & Castelli, D. M. (2008). National physical education standards: a summary of student performance and its correlates. *Research Quarterly for Exercise & Sport, 79*(4), 495-505.

Estevan, I., Molina-García, J., Bowe, S. J., Álvarez, O., Castillo, I., & Barnett, L. M. (2018). Who can best report on children's motor competence: Parents, teachers, or the children themselves? *Psychology of Sport and Exercise, 34*, 1-9.

Estevan, I., Molina-García, J., Queralt, A., Álvarez, O., Castillo, I., & Barnett, L. (2017). Validity and reliability of the Spanish version of the test of gross motor development–3. *Journal of Motor Learning and Development, 5*(1), 69-81.

Evaggelinou, C., Tsigilis, N., & Papa, A. (2002). Construct validity of the Test of Gross Motor Development: a cross-validation approach. *Adapted physical activity quarterly, 19*(4), 483-495. https://journals.humankinetics.com/view/journals/apaq/19/4/article-p483.xml

Eyre, E. L., Walker, L. J., & Duncan, M. J. (2018). Fundamental movement skills of children living in england: the role of ethnicity and native English language. *Perceptual and motor skills, 125*(1), 5-20.

Farmer, O., Belton, S., & O'Brien, W. (2017). The relationship between actual fundamental motor skill proficiency, perceived motor skill confidence and competence, and physical activity in 8–12-year-old irish female youth. *Sports, 5*(4), 74.

Ferreira, L., Vieira, J. L. L., Rocha, F. F. d., Silva, P. N. d., Cheuczuk, F., Caçola, P., & Chaves, R. N. d. (2020). Percentile curves for Brazilian children evaluated with the Bruininks-Oseretsky Test of Motor Proficiency. *Revista Brasileira de Cineantropometria Desempenho Humano, 22*. https://doi.org/https://doi.org/10.1590/1980-0037.2020v22e65027

Field, S. C., Bosma, C. B. E., & Temple, V. A. (2020). Comparability of the test of gross motor development–Second edition and the test of gross motor development–Third edition. *Journal of Motor Learning and Development, 8*, 107-125.

Finch, P. (2015). *Evidence to the NHS Pay Review Body.*

Fisher, A., Reilly, J. J., Kelly, L. A., Montgomery, C., Williamson, A., Paton, J. Y., & Grant, S. (2005). Fundamental movement skills and habitual physical activity in young children. *Medicine and science in sports and exercise, 37*(4), 684-688.

Fisher, W. P. (1992). Reliability Statistics. *Rasch Measurement Transactions, 6*(3), 238.

Folio, M. R., & Fewell, R. R. (1983). *Peabody developmental motor scales and activity cards*. **PRO-ED**.

Folio, M. R., & Fewell, R. R. (2000). *PDMS-2: Peabody Development Motor Scales*. PRO-ED.

Foulkes, J., Knowles, Z., Fairclough, S. J., Stratton, G., O'dwyer, M., Ridgers, N., & Foweather, L. (2015). Fundamental movement skills of preschool children in Northwest England. *Perceptual and motor skills, 121*(1), 260-283.

Furtado Jr, O., & Gallagher, J. D. (2012). The reliability of classification decisions for the Furtado-Gallagher computerized observational movement pattern assessment system—FG-COMPASS. *Research quarterly for exercise and sport, 83*(3), 383-390.

Furtado, O. J. (2009). *Development and initial validation of the Furtado-Gallagher Computerized Observational Movement Pattern Assessment System-FG-COMPASS* University of Pittsburgh]. Unpublished.

Gabbard, C., & Rodrigues, L. (2008). Optimizing early brain and motor development through movement. *Early Childhood News*.

Gabbard, C. P. (2011). *Lifelong motor development*. Pearson Higher Ed.

Gale, C. R., O'Callaghan, F. J., Godfrey, K. M., Law, C. M., & Martyn, C. N. (2004). Critical periods of brain growth and cognitive function in children. *Brain, 127*(2), 321-329.

Gallahue, D. L., Ozmun, J. C., & Goodway, J. D. (2012). *Understanding motor development: Infants, children, adolescents, adults* (7th ed.). M.-G. Hill.

García-Marín, P., Fernández-López, N., & English, C. E. (2020). Motor Skills Competence in Preschool Education. *Apunts Educación Física y Deportes, 141*, 21-32.

Garcia, C. (1994). Gender differences in young children's interactions when learning fundamental motor skills. *Research Quarterly for Exercise & Sport, 65*(3), 213-225.

Garn, A. C., & Webster, E. K. (2018). Reexamining the factor structure of the test of gross motor development–Second edition: Application of exploratory structural equation modeling. *Measurement in Physical Education and Exercise Science, 22*(3), 200-212.

Gibson, E. J. (1987). Introductory essay: What does infant perception tell us about theories of perception? *Journal of Experimental Psychology: Human Perception & Performance, 13*(4), 515.

Goodway, J. D., Robinson, L. E., & Crowe, H. (2010). Gender differences in fundamental motor skill development in disadvantaged preschoolers from two geographical regions. *Research Quarterly for Exercise & Sport, 81*(1), 17-24.

Goodway, J. D., & Smith, D. W. (2005). Keeping all children healthy: challenges to leading an active lifestyle for preschool children qualifying for at-risk programs. *Family & Community Health, 28*(2), 142-155.

Griffiths, A., Toovey, R., Morgan, P. E., & Spittle, A. J. (2018). Psychometric properties of gross motor assessment tools for children: a systematic review. *BMJ open, 8*(10), e021734.

Grimpampi, E., Masci, I., Pesce, C., & Vannozzi, G. (2016). Quantitative assessment of developmental levels in overarm throwing using wearable inertial sensing technology. *Journal of Sports Sciences, 34*(18), 1759-1765.

Guan, H., Okely, A. D., Aguilar-Farias, N., del Pozo Cruz, B., Draper, C. E., El Hamdouchi, A., Florindo, A. A., Jáuregui, A., Katzmarzyk, P. T., & Kontsevaya, A. (2020). Promoting healthy movement behaviours among children during the COVID-19 pandemic. *The Lancet Child & Adolescent Health, 4*(6), 416-418.

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1· 6 million participants. *The Lancet Child & Adolescent Health, 4*(1), 23-35.

Hambleton, R. K. (2000). Emergence of item response modeling in instrument development and data analysis. *Medical care, 38*, 60-65.

[Record #348 is using a reference type undefined in this output style.]

Hamilton, M. L., & Tate, A. (2002). Constraints on throwing behavior of children. In *Motor development: Research and Review* (Vol. 2, pp. 49-61). NASPE Publications.

Hammond, A., Prior, Y., Horton, M. C., Tennant, A., & Tyson, S. (2018). The psychometric properties of the Evaluation of Daily Activity Questionnaire in seven musculoskeletal conditions. *Disability and rehabilitation, 40*(17), 2070-2080. https://www.tandfonline.com/doi/pdf/10.1080/09638288.2017.1323027?needAccess=true

Hardy, L. L., Reinten-Reynolds, T., Espinel, P., Zask, A., & Okely, A. D. (2012). Prevalence and correlates of low fundamental movement skill competency in children. *Pediatrics, 130*(2), e390-e398.

Harris, J., Cale, L., & Musson, H. (2012). The predicament of primary physical education: A consequence of 'insufficient'ITT and 'ineffective'CPD? *Physical Education and Sport Pedagogy, 17*(4), 367-381.

Haubenstricker, J., & Seefeldt, V. (1986). *Acquisition of motor skills during childhood*. American Alliance for Health, Physical Education, Recreation and Dance.

Haynes, S. N., Richard, D., & Kubany, E. S. (1995). Content validity in psychological assessment: A functional approach to concepts and methods. *Journal of Psychological Assessment, 7*(3), 238-247.

Health Education England. (2017). *An Investigation into the Occupational Therapy Workforce in London*. https://www.rcot.co.uk/news/new-report

Hendersen, S., Sugden, D., & Barnett, A. (2007). *Movement assessment battery for children–2 examiner's manual*. Harcourt Assessment.

Henderson, S., Sugden, D., & Barnett, A. (1992). *Movement Assessment Battery for Children*. The Psychological Corporation.

Henrique, R. S., Stodden, D. F., Fransen, J., Feitoza, A. H., Ré, A. H., Martins, C. M., dos Prazeres, T. M., & Cattuzzo, M. T. (2020). Is motor competence associated with the risk of central obesity in preschoolers? *American Journal of Human Biology, 32*(3), e23364.

Hoeboer, J., De Vries, S., Krijger-Hombergen, M., Wormhoudt, R., Drent, A., Krabben, K., & Savelsbergh, G. (2016). Validity of an Athletic Skills Track among 6-to 12-year-old children. *Journal of Sports Sciences, 34*(21), 2095-2105. https://www.tandfonline.com/doi/full/10.1080/02640414.2016.1151920

Hoeboer, J., Krijger-Hombergen, M., Savelsbergh, G., & De Vries, S. (2018). Reliability and concurrent validity of a motor skill competence test among 4-to 12-year old children. *Journal of Sports Sciences, 36*(14), 1607-1613. https://www.tandfonline.com/doi/full/10.1080/02640414.2017.1406296

Holm, I., Tveter, A. T., Aulie, V. S., & Stuge, B. (2013). High intra-and inter-rater chance variation of the movement assessment battery for children 2, ageband 2. *Research in Developmental Disabilities, 34*(2), 795-800. https://www.sciencedirect.com/science/article/abs/pii/S0891422212002715?via%3Dihub

Houwen, S., Hartman, E., Jonker, L., & Visscher, C. (2010). Reliability and validity of the TGMD-2 in primary-school-age children with visual impairments. *Adapted physical activity quarterly, 27*(2), 143-159. https://journals.humankinetics.com/view/journals/apaq/27/2/article-p143.xml

Hua, J., Gu, G., Meng, W., & Wu, Z. (2013). Age band 1 of the Movement Assessment Battery for Children-: exploring its usefulness in mainland China. *Research in Developmental Disabilities, 34*(2), 801-808. https://www.sciencedirect.com/science/article/abs/pii/S0891422212002673?via%3Dihub

Hulteen, R. M., Barnett, L. M., Morgan, P. J., Robinson, L. E., Barton, C. J., Wrotniak, B. H., & Lubans, D. R. (2018). Development, content validity and test-retest reliability of the Lifelong Physical Activity Skills Battery in adolescents. *Journal of Sports Sciences, 36*(20), 2358-2367. https://www.tandfonline.com/doi/full/10.1080/02640414.2018.1458392

Hulteen, R. M., Barnett, L. M., True, L., Lander, N. J., del Pozo Cruz, B., & Lonsdale, C. (2020). Validity and reliability evidence for motor competence assessments in children and adolescents: A systematic review. *Journal of Sports Sciences, 38*(15), 1717-1798.

Hulteen, R. M., Morgan, P. J., Barnett, L. M., Stodden, D. F., & Lubans, D. R. (2018). Development of foundational movement skills: A conceptual model for physical activity across the lifespan. *Sports Medicine, 48*(7), 1533-1540.

Iatridou, G., & Dionyssiotis, Y. (2013). Reliability of balance evaluation in children with cerebral palsy. *Hippokratia, 17*(4), 303-306. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4097408/pdf/hippokratia-17-303.pdf

Information Services Division Scotland. (2018). *Allied Health Professionals – Musculoskeletal Waiting Times in NHS Scotland*. https://www.isdscotland.org/Health-Topics/Waiting-Times/Publications/2018-06-19/2018-06-19-AHPMSK-Summary.pdf

Issartel, J., McGrane, B., Fletcher, R., O'Brien, W., Powell, D., & Belton, S. (2017). A cross-validation study of the TGMD-2: The case of an adolescent population. *Journal of science and medicine in sport, 20*(5), 475-479. https://www.jsams.org/article/S1440-2440(16)30213-4/fulltext

Jaikaew, R., & Satiansukpong, N. (2019). Movement Assessment Battery for Children-(MABC2): Cross-Cultural Validity, Content Validity, and Interrater Reliability in Thai Children. *Occupational Therapy International, 2019*. https://doi.org/https://doi.org/10.1155/2019/4086594

Jiménez-Díaz, J., Salazar, W., & Morera-Castro, M. (2013). Diseño y validación de un instrumento para la evaluación de patrones básicos de movimiento. Motricidad [Design and validation of an instrument for the evaluation of basic movement patterns. Motricity]. *European Journal of Human Movement, 31*(0), 87-97.

Jírovec, J., Musálek, M., & Mess, F. (2019). Test of motor proficiency second edition (BOT-2): compatibility of the complete and Short Form and its usefulness for middle-age school children. *Frontiers in pediatrics, 7*, 1-7.

Joffe, H. (2011). Thematic Analysis. In D. Harper & A. Thompson (Eds.), *Qualitative research methods in mental health and psychotherapy: A guide for students and practitioners*. John Wiley & Sons.

Jones, D., Innerd, A., Giles, E. L., & Azevedo, L. B. (2020). Association between fundamental motor skills and physical activity in the early years: A systematic review and meta-analysis. *Journal of sport and health science, 00*, 1-11.

Kalaja, S. P., Jaakkola, T. T., Liukkonen, J. O., & Digelidis, N. (2012). Development of junior high school students' fundamental movement skills and physical activity in a naturalistic physical education setting. *Physical Education and Sport Pedagogy, 17*(4), 411-428.

[Record #342 is using a reference type undefined in this output style.]

Kelly, B., Mason, D., Petherick, E. S., Wright, J., Mohammed, M. A., & Bates, C. (2016). Maternal health inequalities and GP provision: investigating variation in consultation rates for women in the Born in Bradford cohort. *Journal of Public Health, 39*(2), e48-e55.

Kelly, L., O'Connor, S., Harrison, A. J., & Ní Chéilleachair, N. J. (2019). Does fundamental movement skill proficiency vary by sex, class group or weight status? Evidence from an Irish primary school setting. *Journal of Sports Sciences, 37*(9), 1055-1063.

Kennedy, J., Brown, T., & Chien, C.-W. (2012). Motor skill assessment of children: is there an association between performance-based, child-report, and parent-report measures of children's motor skills? *Physical & occupational therapy in pediatrics, 32*(2), 196-209.

Kim, S., Kim, M. J., Valentini, N. C., & Clark, J. E. (2014). Validity and reliability of the TGMD-2 for South Korean children. *Journal of motor behavior, 46*(5), 351-356. https://www.tandfonline.com/doi/full/10.1080/00222895.2014.914886

Kim, Y., Park, I., & Kang, M. (2012). Examining rater effects of the TGMD-2 on children with intellectual disability. *Adapted physical activity quarterly, 29*(4), 346-365. https://journals.humankinetics.com/view/journals/apaq/29/4/article-p346.xml

King, D. B., O'Rourke, N., & DeLongis, A. (2014). Social media recruitment and online data collection: A beginner’s guide and best practices for accessing low-prevalence and hard-to-reach populations. *Canadian Psychology/Psychologie canadienne, 55*(4), 240 - 249. https://doi.org/https://doi.org/10.1037/a0038087

Kininmonth, A. R., Smith, A. D., Llewellyn, C. H., & Fildes, A. (2020). Socioeconomic status and changes in appetite from toddlerhood to early childhood. *Apetite, 146*, 104517.

Kiphard, E., & Schilling, F. (2007). *Körperkoordinationstest für Kinder KTK. Manual. 2. überarbeitete und ergänzte Auflage*. Beltz Test.

Kiphard, E., & Shilling, F. (1974). *Körperkoordinationtest für Kinder.* Beltz test.

Kita, Y., Suzuki, K., Hirata, S., Sakihara, K., Inagaki, M., & Nakai, A. (2016). Applicability of the Movement Assessment Battery for Children-to Japanese children: A study of the Age Band 2. *Brain and Development, 38*(8), 706-713. https://www.brainanddevelopment.com/article/S0387-7604(16)30001-8/fulltext

Klingberg, B., Schranz, N., Barnett, L. M., Booth, V., & Ferrar, K. (2018). The feasibility of fundamental movement skill assessments for pre-school aged children. *Journal of Sports Sciences, 37*, 1-9.

Kokštejn, J., Musálek, M., & Tufano, J. J. (2017). Are sex differences in fundamental motor skills uniform throughout the entire preschool period? *PloS one, 12*(4), e0176556.

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of chiropractic medicine, 15*(2), 155-163. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4913118/pdf/main.pdf

Koutsouris, G., & Norwich, B. (2018). What exactly do RCT findings tell us in education research? *British Educational Research Journal, 44*(6), 939-959.

Kracht, C. L., Webster, E. K., & Staiano, A. E. (2020). Relationship between the 24-Hour Movement Guidelines and fundamental motor skills in preschoolers. *Journal of Science & Medicine in Sport, 23*(12), 1185-1190.

Krueger, R. A., & Casey, M. A. (2014). *Focus groups: A practical guide for applied research*. Sage publications.

Laguilles, J. S., Williams, E. A., & Saunders, D. B. (2011). Can lottery incentives boost web survey response rates? Findings from four experiments. *Research in Higher Education, 52*(5), 537-553.

Lalor, A., Brown, T., & Murdolo, Y. (2016). Relationship between children's performance-based motor skills and child, parent, and teacher perceptions of children's motor abilities using self/informant-report questionnaires. *Australian Occupational Therapy Journal, 63*(2), 105-116.

Lander, N., Morgan, P. J., Salmon, J., Logan, S. W., & Barnett, L. M. (2017). The reliability and validity of an authentic motor skill assessment tool for early adolescent girls in an Australian school setting. *Journal of science and medicine in sport, 20*(6), 590-594. https://www.jsams.org/article/S1440-2440(17)30238-4/pdf

Lander, N., Nahavandi, D., Mohamed, S., Essiet, I., & Barnett, L. M. (2020). Bringing objectivity to motor skill assessment in children. *Journal of Sports Sciences*, 1-11.

Laukkanen, A., Bardid, F., Lenoir, M., Lopes, V. P., Vasankari, T., Husu, P., & Sääkslahti, A. (2020). Comparison of motor competence in children aged 6-9 years across northern, central, and southern European regions. *Scandinavian journal of medicine & science in sports, 30*(2), 349-360.

Lawson, C., Eyre, E. L., Tallis, J., & Duncan, M. J. (2021). Fundamental Movement Skill Proficiency among British Primary School Children: Analysis at a Behavioral Component Level. *Perceptual and motor skills, 128*(2), 625-648.

Li, Y.-C., Kwan, M. Y., & Cairney, J. (2019). Motor coordination problems and psychological distress in young adults: A test of the Environmental Stress Hypothesis. *Research in developmental disabilities, 84*, 112-121.

Liamputtong, P. (2011). *Focus group methodology: Principle and practice*. Sage Publications.

Liao, H.-F., Mao, P.-J., & Hwang, A.-W. (2001). Test–retest reliability of balance tests in children with cerebral palsy. *Developmental medicine and child neurology, 43*(3), 180-186. https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/j.1469-8749.2001.tb00184.x?download=true

Linacre, J. (1994). Sample size and item calibration stability. *Rasch Mes Trans., 7*, 328.

Liong, G. H., Ridgers, N. D., & Barnett, L. M. (2015). Associations between skill perceptions and young children's actual fundamental movement skills. *Perceptual and motor skills, 120*(2), 591-603.

Logan, S., Robinson, L. E., Wilson, A., & Lucas, W. (2012). Getting the fundamentals of movement: a meta-analysis of the effectiveness of motor skill interventions in children. *Child: care, health and development, 38*(3), 305-315.

Logan, S. W., Barnett, L. M., Goodway, J. D., & Stodden, D. F. (2017). Comparison of performance on process-and product-oriented assessments of fundamental motor skills across childhood. *Journal of Sports Sciences, 35*(7), 634-641. https://www.tandfonline.com/doi/full/10.1080/02640414.2016.1183803

Logan, S. W., Robinson, L. E., Getchell, N., Webster, E. K., Liang, L.-Y., & Golden, D. (2014). Relationship between motor competence and physical activity: A systematic review. *Research Quarterly for Exercise & Sport, 85*(S1), A14.

Logan, S. W., Robinson, L. E., Rudisill, M. E., Wadsworth, D. D., & Morera, M. (2014). The comparison of school-age children's performance on two motor assessments: the Test of Gross Motor Development and the Movement Assessment Battery for Children. *Physical Education and Sport Pedagogy, 19*(1), 48-59.

Longmuir, P. E., Boyer, C., Lloyd, M., Borghese, M. M., Knight, E., Saunders, T. J., Boiarskaia, E., Zhu, W., & Tremblay, M. S. (2017). Canadian Agility and Movement Skill Assessment (CAMSA): Validity, objectivity, and reliability evidence for children 8–12 years of age. *Journal of sport and health science, 6*(2), 231-240. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6189007/pdf/main.pdf

Loovis, E. M., & Ersing, W. F. (1979). *Assessing and programming gross motor development for children*. College Town Press.

Lopes, V. P., Saraiva, L., & Rodrigues, L. P. (2018). Reliability and construct validity of the test of gross motor development-2 in Portuguese children. *International Journal of Sport and Exercise Psychology, 16*(3), 250-260.

Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M., & Okely, A. D. (2010). Fundamental movement skills in children and adolescents. *Sports Medicine, 40*(12), 1019-1035.

Lucas, B. R., Latimer, J., Doney, R., Ferreira, M. L., Adams, R., Hawkes, G., Fitzpatrick, J. P., Hand, M., Oscar, J., & Carter, M. (2013). The Bruininks-Oseretsky test of motor proficiency-short form is reliable in children living in remote Australian aboriginal communities. *BMC pediatrics, 13*(1), 135.

Macdonald, K., Milne, N., Orr, R., & Pope, R. (2018). Relationships between motor proficiency and academic performance in mathematics and reading in school-aged children and adolescents: a systematic review. *International Journal of Environmental Research and Public Health, 15*(8), 1603.

Macdonald, K., Milne, N., Orr, R., & Pope, R. (2020). Associations between motor proficiency and academic performance in mathematics and reading in year 1 school children: a cross-sectional study. *BMC pediatrics, 20*(1), 1-11.

Maeng, H., Webster, E. K., Pitchford, E. A., & Ulrich, D. A. (2017). Inter-and Intrarater Reliabilities of the Test of Gross Motor Development—Third Edition Among Experienced TGMD-2 Raters. *Adapted physical activity quarterly, 34*(4), 442-455. https://journals.humankinetics.com/view/journals/apaq/34/4/article-p442.xml

Magistro, D., Piumatti, G., Carlevaro, F., Sherar, L. B., Esliger, D. W., Bardaglio, G., Magno, F., Zecca, M., & Musella, G. (2020). Psychometric proprieties of the Test of Gross Motor Development–Third Edition in a large sample of Italian children. *Journal of Science & Medicine in Sport, In Press*. https://doi.org/https://doi.org/10.1016/j.jsams.2020.02.014

Magno, C. (2009). Demonstrating the difference between classical test theory and item response theory using derived test data. *The international Journal of Educational & Psychological assessment, 1*(1), 1-11.

Maher, S. J., Schott, N., Lander, N. J., Hinkley, T., & Barnett, L. M. (2018). A comparison of parent report and actual motor competence in young children. *Australian Occupational Therapy Journal, 65*(5), 387-394.

Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity* (2nd Edition ed.). Human kinetics.

Mallett, R., Hagen-Zanker, J., Slater, R., & Duvendack, M. (2012). The benefits and challenges of using systematic reviews in international development research. *Journal of development effectiveness, 4*(3), 445-455.

Mancini, V., Rudaizky, D., Howlett, S., Elizabeth-Price, J., & Chen, W. (2020). Movement difficulties in children with ADHD: Comparing the long-and short-form Bruininks–Oseretsky Test of Motor Proficiency—Second Edition (BOT-2). *Australian Occupational Therapy Journal, 67*(2), 153-161.

Marais, I., & Andrich, D. (2008). Effects of varying magnitude and patterns of local dependence in the unidimensional Rasch model. *Journal of Applied Measurement, 9*(2), 1-20.

Martins, C., Bandeira, P. F. R., Souza Filho, A., Bezerra, T., Clark, C., Webster, E. K., Mota, J., & Duncan, M. (2021). The combination of three movement behaviours is associated with object control skills, but not locomotor skills, in preschoolers. *European Journal of Pediatrics, 180*(5), 1505-1512.

Martins, C. M. d. L., Bandeira, P. F. R., Lemos, N. B. A. G., Bezerra, T. A., Clark, C. C. T., Mota, J., & Duncan, M. J. (2020). A Network Perspective on the Relationship between Screen Time, Executive Function, and Fundamental Motor Skills among Preschoolers. *International Journal of Environmental Research & Public Health, 17*(23), 8861.

Martins, C. M. d. L., Clark, C. C. T., Ribeiro Bandeira, P. F., Mota, J., & Duncan, M. J. (2020). Association between compliance with the 24-hour movement guidelines and fundamental movement skills in preschoolers: A network perspective. *International Journal of Environmental Research & Public Health, 17*(15), 5443.

Masters, G. N. (1982). A Rasch model for partial credit scoring. *Psychometrika, 47*(2), 149-174.

Matarma, T., Lagström, H., Löyttyniemi, E., & Koski, P. (2020). Motor Skills of 5-Year-Old Children: Gender Differences and Activity and Family Correlates. *Perceptual and motor skills, 127*(2), 367-385.

Matthews-King, A. (2018). GP vacancies rise to record levels despite recruitment pledge, survey suggests. *The Independent*.

Maxwell, S. E., Lau, M. Y., & Howard, G. S. (2015). Is psychology suffering from a replication crisis? What does “failure to replicate” really mean? *American Psychologist, 70*(6), 487-495.

McBride, M. (2020). Do Covid-19 restrictions spell the end of PE, art and music in school? *The Irish Times*.

McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochemia medica: Biochemia medica, 22*(3), 276-282.

McKenzie, T. L., Sallis, J. F., Broyles, S. L., Zive, M. M., Nader, P. R., Berry, C. C., & Brennan, J. J. (2002). Childhood movement skills: predictors of physical activity in Anglo American and Mexican American adolescents? *Research Quarterly for Exercise & Sport, 73*(3), 238-244.

Menard, S. (2010). *Logistic Regression: From Introductory to Advanced Concepts and Applications*. SAGE Publications, Inc. https://doi.org/10.4135/9781483348964

Michie, S., Atkins, L., & West, R. (2014). *The behaviour change wheel: a guide to designing interventions.* . Silverback Publishing.

Michie, S., Van Stralen, M. M., & West, R. (2011). The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implementation science, 6*(1), 42.

Mickle, K. J., Munro, B. J., & Steele, J. R. (2011). Gender and age affect balance performance in primary school-aged children. *Journal of Science & Medicine in Sport, 14*(3), 243-248.

Missiuna, C., Pollock, N., Campbell, W., DeCola, C., Hecimovich, C., Sahagian Whalen, S., Siemon, J., Song, K., Gaines, R., & Bennett, S. (2017). Using an innovative model of service delivery to identify children who are struggling in school. *British Journal of Occupational Therapy, 80*(3), 145-154.

Missiuna, C., Rivard, L., & Bartlett, D. (2003). Early identification and risk management of children with developmental coordination disorder. *Pediatric Physical Therapy, 15*(1), 32-38.

Mlinac, M. E., & Feng, M. C. (2016). Assessment of activities of daily living, self-care, and independence. *Archives of Clinical Neuropsychology, 31*(6), 506-516.

Mokkink, L. B., Terwee, C., Patrick, D., Alonso, J., Stratford, P., Knol, D., Bouter, L., & De Vet, H. (2010a). International consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes: results of the COSMIN study. *Journal of Clinical Epidemiology, 63*(7), 734-745.

Mokkink, L. B., Terwee, C. B., Patrick, D. L., Alonso, J., Stratford, P. W., Knol, D. L., Bouter, L. M., & De Vet, H. C. (2010b). The COSMIN checklist for assessing the methodological quality of studies on measurement properties of health status measurement instruments: an international Delphi study. *Quality of Life Research, 19*(4), 539-549. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2852520/pdf/11136_2010_Article_9606.pdf

Moreira, J. P. A., Lopes, M. C., Miranda-Júnior, M. V., Valentini, N. C., Lage, G. M., & Albuquerque, M. R. (2019). Körperkoordinationstest Für Kinder (KTK) for Brazilian children and adolescents: Factor score, factor analysis, and invariance. *Frontiers in Psychology, 10*, 1-11.

Morgan, D. L. (1996). Focus groups. *Annual review of sociology, 22*(1), 129-152.

Morley, D., Till, K., Ogilvie, P., & Turner, G. (2015). Influences of gender and socioeconomic status on the motor proficiency of children in the UK. *Human movement science, 44*, 150-156.

Mortimer, D. (2020). Coronavirus has driven a coach and horses through the NHS budget. We badly need more funding. *The Independent*

Müller, R., & Büttner, P. (1994). A critical discussion of intraclass correlation coefficients. *Statistics in Medicine, 13*(23-24), 2465-2476.

National Association for Sport and Physical Education. (2010). *PE Metrics: Assessing national standards 1-6 in elementary school*. NASPE.

National Association for Sport and Physical Education. (2011). *PE metrics: Assessing national standards 1-6 in secondary school.* NASPE.

National Audit Office. (2016). *Financial Sustainability of the NHS*.

Nazroo, J. Y. (2003). The structuring of ethnic inequalities in health: economic position, racial discrimination, and racism. *American journal of public health, 93*(2), 277-284.

Newby, V. A., Conner, G. R., Grant, C. P., & Bunderson, C. V. (2009). The Rasch model and additive conjoint measurement. *Journal of Applied Measurement, 10*, 348-354.

Newell, K. (1986). *Constraints on the development of coordination*. Martinus Nijhoff.

NHS. (2019). *Developmental co-ordination disorder (dyspraxia) in children*. https://www.nhs.uk/conditions/developmental-coordination-disorder-dyspraxia/diagnosis/

Nicola, K., Waugh, J., Charles, E., & Russell, T. (2018). The feasibility and concurrent validity of performing the Movement Assessment Battery for Children–2nd Edition via telerehabilitation technology. *Research in Developmental Disabilities, 77*, 40-48.

Niemeijer, A. S., Van Waelvelde, H., & Smits-Engelsman, B. C. (2015). Crossing the North Sea seems to make DCD disappear: cross-validation of Movement Assessment Battery for Children-2 norms. *Human movement science, 39*, 177-188.

Niemistö, D., Finni, T., Cantell, M., Korhonen, E., & Sääkslahti, A. (2020). Individual, Family, and Environmental Correlates of Motor Competence in Young Children: Regression Model Analysis of Data Obtained from Two Motor Tests. *International Journal of Environmental Research and Public Health, 17*(7), 2548.

Nilsen, A. K. O., Anderssen, S. A., Johannessen, K., Aadland, K. N., Ylvisaaker, E., Loftesnes, J. M., & Aadland, E. (2020). Bi-directional prospective associations between objectively measured physical activity and fundamental motor skills in children: a two-year follow-up. *International Journal of Behavioural Nutrition and Physical Activity, 17*(1). https://doi.org/https://doi.org/10.1186/s12966-019-0902-6

Novak, A. R., Bennett, K. J., Beavan, A., Pion, J., Spiteri, T., Fransen, J., & Lenoir, M. (2017). The applicability of a short form of the Körperkoordinationstest für Kinder for measuring motor competence in children aged 6 to 11 years. *Journal of Motor Learning and Development, 5*(2), 227-239.

NSW Department of Education and Training. (2000). *Get skilled: Get active. A K-6 resource to support the teaching of fundament skills.* . NSW Department of Education and Training.

Numminen, P. (1995). *APM inventory: manual and test booklet for assessing pre-school children's perceptual and basic motor skills*. LIKES.

O'Brien, W., Belton, S., & Issartel, J. (2016). Fundamental movement skill proficiency amongst adolescent youth. *Physical Education and Sport Pedagogy, 21*(6), 557-571.

Office for National Statistics. (2011). *Population of England and Wales*. U. Government. https://www.ethnicity-facts-figures.service.gov.uk/uk-population-by-ethnicity/national-and-regional-populations/population-of-england-and-wales/latest#by-ethnicity

Ofsted. (2013). *Beyond 2012 - outstanding physical education for all*. H. Government. https://www.gov.uk/government/publications/beyond-2012-outstanding-physical-education-for-all

Ofsted. (2020). *COVID-19 series: briefing on schools, October 2020*. H. Government. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/933490/COVID-19_series_briefing_on_schools_October_2020.pdf

Okely, A. D., Booth, M. L., & Patterson, J. W. (2001). Relationship of physical activity to fundamental movement skills among adolescents. *Medicine and science in sports and exercise, 33*(11), 1899-1904.

Okuda, P. M. M., Pangelinan, M., Capellini, S. A., & Cogo-Moreira, H. (2019). Motor skills assessments: support for a general motor factor for the Movement Assessment Battery for Children-2 and the Bruininks-Oseretsky Test of Motor Proficiency-2. *Trends in psychiatry & psychotherapy*

41(1), 51-59.

Palmer, K. K., Stodden, D. F., Ulrich, D. A., & Robinson, L. E. (2021). Using Process- and Product-oriented Measures to Evaluate Changes in Motor Skills across an Intervention. *Measurement in Physical Education and Exercise Science*, 1-10. https://doi.org/10.1080/1091367X.2021.1876069

Papert, S., & Harel, I. (1991). Situating constructionism. *Constructionism, 36*(2), 1-11.

Perera, N. (2020). *Analysis: school funding* | *Budget 2020*. E. P. Institute. https://epi.org.uk/publications-and-research/school-funding-budget-2020/2020

Physical Health Education Canada. (2014). Development of passport for life. *Physical & Health Education Journal, 80*(2), 18-21.

Pill, S., & Harvey, S. (2019). A narrative review of children’s movement competence research 1997-2017. *Physical Culture & Sport, 81*(1), 47-74.

Pombo, A., Luz, C., de Sá, C., Rodrigues, L. P., & Cordovil, R. (2021). Effects of the COVID-19 Lockdown on Portuguese Children’s Motor Competence. *Children, 8*(3), 199.

Pombo, A., Luz, C., Rodrigues, L. P., & Cordovil, R. (2020). COVID-19 Confinement In Portugal: Effects On The Household Routines Of Children Under 13. *Research Square*, 1-16. https://doi.org/https://doi.org/10.21203/rs.3.rs-45764/v1

Preston, N., Horton, M., Levesley, M., Mon-Williams, M., & O'Connor, R. (2018). Development of a parent-reported questionnaire evaluating upper limb activity limitation in children with cerebral palsy. *Physiotherapy Research International, 23*(1), e1684.

Preston, N., Magallon, S., Hill, L. J., Andrews, E., Ahern, S. M., & Mon-Williams, M. (2017). A systematic review of high quality randomized controlled trials investigating motor skill programmes for children with developmental coordination disorder. *Clinical Rehabilitation, 31*(7), 857-870.

Progar, Š., Sočan, G., & Peč, M. (2008). An empirical comparison of item response theory and classical test theory. *Horizons of Psychology, 17*(3), 5-24.

Psotta, R., & Abdollahipour, R. (2017). Factorial Validity of the Movement Assessment Battery for Children—2nd Edition (MABC-2) in 7-16-Year-Olds. *Perceptual and motor skills, 124*(6), 1051-1068. https://journals.sagepub.com/doi/10.1177/0031512517729951?url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org&rfr_dat=cr_pub%3Dpubmed&

Public Health England. (2020a). *Bradford Local Authority Health Profile 2019*.

Public Health England. (2020b). *Public Health Outcomes Framework*.

Rasch, G. (1960). *Studies in mathematical psychology: I. Probabilistic models for some intelligence and attainment tests*. Chicago University Press.

Raynor, P., & Group, B. i. B. C. (2008). Born in Bradford, a cohort study of babies born in Bradford, and their parents: protocol for the recruitment phase. *BMC public health, 8*(1), 1-13. https://doi.org/10.1186/1471-2458-8-327

Ré, A. H., Logan, S. W., Cattuzzo, M. T., Henrique, R. S., Tudela, M. C., & Stodden, D. F. (2018). Comparison of motor competence levels on two assessments across childhood. *Journal of Sports Sciences, 36*(1), 1-6. https://www.tandfonline.com/doi/full/10.1080/02640414.2016.1276294

Rife, S. C., Cate, K. L., Kosinski, M., & Stillwell, D. (2016). Participant recruitment and data collection through Facebook: The role of personality factors. *International Journal of Social Research Methodology, 19*(1), 69-83. https://doi.org/https://doi.org/10.1080/13645579.2014.957069

Rikhy, S., Tough, S., Trute, B., Benzies, K., Kehler, H., & Johnston, D. W. (2010). Gauging knowledge of developmental milestones among Albertan adults: a cross-sectional survey. *BMC public health, 10*(1), 183.

Rintala, P. O., Sääkslahti, A. K., & Iivonen, S. (2017). Reliability assessment of scores from video-recorded TGMD-3 performances. *Journal of Motor Learning and Development, 5*(1), 59-68.

Rodríguez-Negro, J., Huertas-Delgado, F. J., & Yanci, J. (2019). Motor skills differences by gender in early elementary education students. *Early Child Development & Care*, 1-11.

Rodriguez, M. C., Wade, T. J., Veldhuizen, S., Missiuna, C., Timmons, B., & Cairney, J. (2019). Emotional and Behavioral Problems in 4-and 5-year old children with and without motor delays. *Frontiers in pediatrics, 7*, 474.

Rösblad, B., & Gard, L. (1998). The assessment of children with developmental coordination disorders in Sweden: A preliminary investigation of the suitability of the movement ABC. *Human movement science, 17*(4-5), 711-719.

Rose, G. (2016). *Visual methodologies: An introduction to researching with visual materials*. sage.

Roth, K., Ruf, K., Obinger, M., Mauer, S., Ahnert, J., Schneider, W., Graf, C., & Hebestreit, H. (2010). Is there a secular decline in motor skills in preschool children? *Scandinavian journal of medicine & science in sports, 20*(4), 670-678.

Routen, A. C., Johnston, J. P., Glazebrook, C., & Sherar, L. B. (2018). Teacher perceptions on the delivery and implementation of movement integration strategies: the CLASS PAL (physically active learning) Programme. *International Journal of Educational Research, 88*, 48-59. https://doi.org/https://doi.org/10.1016/j.ijer.2018.01.003

Rudd, J., Barnett, L., Butson, M., Farrow, D., Berry, J., & Polman, R. (2015). Fundamental movement skills are more than run, throw and catch: The role of stability skills. *J PLoS One, 10*(10), 1-15.

Rudd, J., Butson, M., Barnett, L., Farrow, D., Berry, J., Borkoles, E., & Polman, R. (2016). A holistic measurement model of movement competency in children. *Journal of Sports Sciences, 34*(5), 477-485. https://www.tandfonline.com/doi/full/10.1080/02640414.2015.1061202

Rudgard, O. (2018). Schools scrap PE time because of exam pressure. https://www.telegraph.co.uk/news/2018/02/19/school-scrap-pe-time-exam-pressure/

Ruiz, L. M., Graupera, J. L., Gutiérrez, M., & Miyahara, M. (2003). The Assessment of Motor Coordination in Children with the Movement ABC test: A Comparative Study among Japan, USA and Spain. *International Journal of Applied Sports Sciences, 15*(1), 22-35.

Rumsby, B. (2015). *Alarming fall in school PE lessons casts doubt over government's commitment to tackling obesity crisis*. http://www.telegraph.co.uk/sport/othersports/schoolsports/11343801/Alarming-fall-in-school-PE-lessons-casts-doubt-over-governments-commitment-to-tackling-obesity-crisis.html.

Sacko, R. S. (2020). MC= MVPA. *Journal of Physical Education, Recreation & Dance, 91*(4), 3-4.

Scheuer, C., Herrmann, C., & Bund, A. (2019). Motor tests for primary school aged children: A systematic review. *Journal of Sports Sciences, 37*(10), 1097-1112.

Schilling, F., & Kiphard, E. (2000). *Körperkoordinationstest für kinder Manual*. Beltz Test GmbH.

Schulz, J., Henderson, S. E., Sugden, D. A., & Barnett, A. L. (2011). Structural validity of the Movement ABC-2 test: Factor structure comparisons across three age groups. *Research in Developmental Disabilities, 32*(4), 1361-1369. https://www.sciencedirect.com/science/article/abs/pii/S0891422211000333?via%3Dihub

Shire, K. A., Atkinson, J., Williams, E. A., Pickavance, J., Magallón, S., Hill, L. J., Waterman, A. H., Sugden, D. A., & Mon-Williams, M. (2021). Developing and Implementing a School-led Motor Intervention for Children with Handwriting Difficulties. *Journal of Occupational Therapy, Schools, and Early Intervention*, 1-17.

Shumway-Cook, A., & Woollacott, M. H. (2007). *Motor control: translating research into clinical practice*. Lippincott Williams & Wilkins.

Simons, J., Daly, D., Theodorou, F., Caron, C., Simons, J., & Andoniadou, E. (2008). Validity and reliability of the TGMD-2 in 7–10-year-old Flemish children with intellectual disability. *Adapted physical activity quarterly, 25*(1), 71-82. https://journals.humankinetics.com/view/journals/apaq/25/1/article-p71.xml

Singh, D. K. A., Rahman, N., Rajikan, R., Zainudin, A., Nordin, N. A. M., Karim, Z. A., & Yee, Y. H. (2015). Balance and motor skills among preschool children aged 3 to 4 years old. *Malaysian Journal of Medicine & Health Sciences, 11*(1), 63-68.

Smaje, C., & Le Grand, J. (1997). Ethnicity, equity and the use of health services in the British NHS. *Social science & medicine, 45*(3), 485-496.

Smits-Engelsman, B. C., Fiers, M. J., Henderson, S. E., & Henderson, L. (2008). Interrater reliability of the movement assessment battery for children. *Physical therapy, 88*(2), 286-294.

Spironello, C., Hay, J., Missiuna, C., Faught, B., & Cairney, J. (2010). Concurrent and construct validation of the short form of the Bruininks-Oseretsky Test of Motor Proficiency and the Movement-ABC when administered under field conditions: implications for screening. *Child: care, health and development, 36*(4), 499-507. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2214.2009.01066.x

Sport England. (2021). *Active Lives Children and Young People Survey: Academic year 2019/20*.

St John, L., Dudley, D., & Cairney, J. (2020). A longitudinal examination of enjoyment of physical education in children with developmental coordination disorder through a physical literacy lens. *PROSPECTS*, 1-13.

Stearns, J. A., Wohlers, B., McHugh, T.-L. F., Kuzik, N., & Spence, J. C. (2019). Reliability and Validity of the PLAY fun Tool with Children and Youth in Northern Canada. *Measurement in Physical Education and Exercise Science, 23*(1), 47-57.

Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Roberton, M. A., Rudisill, M. E., Garcia, C., & Garcia, L. E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest, 60*(2), 290-306.

Stratton, G., Foweather, L., & Hughes, H. (2017). *Dragon Challenge: A National Indicator for Children's Physical Literacy in Wales. Surveillance Report January 2017*. S. Wales.

Streiner, D. L. (2003). Starting at the beginning: an introduction to coefficient alpha and internal consistency. *Journal of personality assessment, 80*(1), 99-103.

Sun, S.-H., Zhu, Y.-C., Shih, C.-L., Lin, C.-H., & Wu, S. K. (2010). Development and initial validation of the preschooler gross motor quality scale. *Research in Developmental Disabilities, 31*(6), 1187-1196.

Supovitz, J., Sirinides, P., & May, H. (2010). How principals and peers influence teaching and learning. *Educational Administration Quarterly, 46*(1), 31-56.

Szczepura, A. (2005). Access to health care for ethnic minority populations. *Postgraduate medical journal, 81*(953), 141-147.

Tan, S. K., Parker, H. E., & Larkin, D. (2001). Concurrent validity of motor tests used to identify children with motor impairment. *Adapted physical activity quarterly, 18*(2), 168-182.

Taylor, M., Yates, A., Meyer, L. H., & Kinsella, P. (2011). Teacher professional leadership in support of teacher professional development. *Teaching and Teacher Education, 27*(1), 85-94. https://doi.org/https://doi.org/10.1016/j.tate.2010.07.005

Tennant, A., & Conaghan, P. G. (2007). The Rasch measurement model in rheumatology: what is it and why use it? When should it be applied, and what should one look for in a Rasch paper? *Arthritis Care & Research, 57*(8), 1358-1362.

Thomas, J. R., & French, K. E. (1985). Gender differences across age in motor performance: A meta-analysis. *Psychological bulletin*

98(2), 260.

Toepoel, V. (2012). Effects of incentives in surveys. In *Handbook of survey methodology for the social sciences* (pp. 209-223). Springer.

Tomaz, S., Jones, R. A., Hinkley, T., Bernstein, S., Twine, R., Kahn, K., Norris, S. A., & Draper, C. E. (2019). Gross motor skills of South African preschool-aged children across different income settings. *Journal of Science & Medicine in Sport, 22*(6), 689-694.

True, L., Brian, A., Goodway, J., & Stodden, D. (2017). Relationships between product-and process-oriented measures of motor competence and perceived competence. *Journal of Motor Learning and Development, 5*(2), 319-335.

Ulrich, D. A. (1983). The standardization of a criterion-referenced test in fundamental motor and physical fitness skills. *Dissertation Abstracts International, 43*(146A).

Ulrich, D. A. (1985). *Test of gross motor development*. Pro-Ed

Ulrich, D. A. (2000). *Test of Gross Motor Development 2nd Edition (TGMD-2)*. Pro-Ed.

Ulrich, D. A. (2016). *Test of gross motor development—3rd edition (TGMD-3)*. University of Michigan.

UNISON. (2019). *NHS staff shortages increase*.

Utesch, T., Bardid, F., Büsch, D., & Strauss, B. (2019). The relationship between motor competence and physical fitness from early childhood to early adulthood: A meta-analysis. *Sports Medicine, 49*(4), 541-551.

Utesch, T., Bardid, F., Huyben, F., Strauss, B., Tietjens, M., De Martelaer, K., Seghers, J., & Lenoir, M. (2016). Using Rasch modeling to investigate the construct of motor competence in early childhood. *Psychology of Sport and Exercise, 24*, 179-187.

Valentini, N. (2012). Validity and reliability of the TGMD-2 for Brazilian children. *Journal of motor behavior, 44*(4), 275-280.

Valentini, N., Ramalho, M., & Oliveira, M. (2014). Movement Assessment Battery for Children-2: Translation, reliability, and validity for Brazilian children. *Research in Developmental Disabilities, 35*(3), 733-740.

Valentini, N. C., Getchell, N., Logan, S. W., Liang, L.-Y., Golden, D., Rudisill, M. E., & Robinson, L. E. (2015). Exploring associations between motor skill assessments in children with, without, and at-risk for developmental coordination disorder. *Journal of Motor Learning and Development, 3*(1), 39-52.

Valentini, N. C., Rudisill, M. E., Bandeira, P. F. R., & Hastie, P. A. (2018). The development of a short form of the Test of Gross Motor Development-2 in Brazilian children: Validity and reliability. *Child: care, health and development, 44*(5), 759-765.

Valentini, N. C., Zanella, L. W., & Webster, E. K. (2017). Test of Gross Motor Development—Third edition: Establishing content and construct validity for Brazilian children. *Journal of Motor Learning and Development, 5*(1), 15-28.

Valle, M. S., Lombardo, L., Cioni, M., & Casabona, A. (2018). Relationship between accuracy and complexity when learning underarm precision throwing. *European journal of sport science, 18*(9), 1217-1225.

Valtr, L., & Psotta, R. (2019). Validity of the Movement Assessment Battery for Children test–2nd edition in older adolescents. *Acta Gymnica, 49*(2), 58-66.

van der Fels, I. M., te Wierike, S. C., Hartman, E., Elferink-Gemser, M. T., Smith, J., & Visscher, C. (2015). The relationship between motor skills and cognitive skills in 4–16 year old typically developing children: A systematic review. *Journal of Science & Medicine in Sport, 18*(6), 697-703.

Van Niekerk, L., Du Toit, D., & Pienaar, A. (2015). The relationship between motor proficiency and academic performance of adolescent learners in Potchefstroom, South Africa: The PAHL study. *African Journal for Physical Health Education, Recreation & Dance, 21*(4.2), 1321-1336.

Van Rossum, T., Foweather, L., Hayes, S., Richardson, D., & Morley, D. (2021). Expert recommendations for the design of a teacher-oriented movement assessment tool for children aged 4-7 years: a Delphi study. *Measurement in Physical Education and Exercise Science*, 1-11. https://doi.org/https://doi.org/10.1080/1091367X.2021.1876070

van Rossum, T., Foweather, L., Richardson, D., Hayes, S. J., & Morley, D. (2018, 2019/04/03). Primary Teachers' Recommendations for the Development of a Teacher-Oriented Movement Assessment Tool for 4–7 Years Children. *Measurement in Physical Education and Exercise Science, 23*(2), 124-134. https://doi.org/10.1080/1091367X.2018.1552587

Van Waelvelde, H., De Weerdt, W., De Cock, P., & Smits-Engelsman, B. (2004). Aspects of the validity of the Movement Assessment Battery for Children. *Human movement science, 23*(1), 49-60.

Van Waelvelde, H., Peersman, W., Lenoir, M., Engelsman, B. C. S., & Henderson, S. E. (2008). The movement assessment battery for children: Similarities and differences between 4-and 5-year-old children from Flanders and the United States. *Pediatric Physical Therapy, 20*(1), 30-38.

Veldman, S. L., Jones, R. A., Chandler, P., Robinson, L. E., & Okely, A. D. (2020). Prevalence and risk factors of gross motor delay in pre-schoolers. *Journal of Paediatrics & Child Health, 56*(4), 571-576.

Veldman, S. L., Santos, R., Jones, R. A., Sousa-Sá, E., & Okely, A. D. (2019). Associations between gross motor skills and cognitive development in toddlers. *Early Human Development, 132*, 39-44.

Venetsanou, F., & Kambas, A. (2010). Environmental factors affecting preschoolers' motor development. *Early Childhood Education Journal, 37*(4), 319-327.

Wagner, M. O., Kastner, J., Petermann, F., & Bös, K. (2011). Factorial validity of the Movement Assessment Battery for Children-2 (age band 2). *Research in Developmental Disabilities, 32*(2), 674-680.

Wagner, M. O., Webster, E. K., & Ulrich, D. A. (2017). Psychometric properties of the Test of Gross Motor Development, (German translation): Results of a pilot study. *Journal of Motor Learning and Development, 5*(1), 29-44.

Ward, B., Thornton, A., Lay, B., Chen, N., & Rosenberg, M. (2020). Can proficiency criteria be accurately identified during real-time fundamental movement skill assessment? *Research Quarterly for Exercise & Sport 91*(1), 64-72.

Webster, E. K., & Ulrich, D. A. (2017). Evaluation of the psychometric properties of the Test of Gross Motor Development—third edition. *Journal of Motor Learning and Development, 5*(1), 45-58.

Wessel, J. A., & Zittel, L. L. (1995). *Smart Start: Preschool Movement Curriculum Designed for Children of All Abilities: a Complete Program of Motor and Play Skills for All Children Ages 3 Through 5, Including Those with Special Developmental and Learning Needs*. Pro-Ed.

Wilkinson, S. (2004). Focus Group Research. In D. Silverman (Ed.), *Qualitative research: Theory, method & practice* (2nd ed., pp. 177-199). Sage Publications.

Williams, H. G., Pfeiffer, K. A., Dowda, M., Jeter, C., Jones, S., & Pate, R. R. (2009). A field-based testing protocol for assessing gross motor skills in preschool children: The children's activity and movement in preschool study motor skills protocol. *Measurement in Physical Education and Exercise Science, 13*(3), 151-165.

Willig, C., & Stainton Rogers, W. (2017). Thematic Analysis In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research*. Sage publications.

Wilson, B. N., Kaplan, B. J., Crawford, S. G., & Dewey, D. (2000). Interrater reliability of the Bruininks-Oseretsky test of motor proficiency–long form. *Adapted physical activity quarterly, 17*(1), 95-110.

Wood, A. P., Imai, S., McMillan, A. G., Swift, D., & DuBose, K. D. (2020). Physical activity types and motor skills in 3-5-year old children: National Youth Fitness Survey. *Journal of Science & Medicine in Sport, 23*(4), 390-395.

World Health Organisation. (2020). *Physical Activity*.

Wright. (1996). Comparing Rasch measurement and factor analysis. *Structural Equation Modeling: A Multidisciplinary Journal, 3*(1), 3-24.

Wright, & Panchapakesan, N. (1969). A procedure for sample-free item analysis. *Educational and Psychological measurement, 29*(1), 23-48.

Wright, B. (1991). Diagnosing Misfit *Rasch Meas Trans, 5*(2), 156.

Wuang, Y.-P., Lin, Y.-H., & Su, C.-Y. (2009). Rasch analysis of the Bruininks–Oseretsky Test of Motor Proficiency-in intellectual disabilities. *Research in Developmental Disabilities, 30*(6), 1132-1144.

https://www.sciencedirect.com/science/article/abs/pii/S0891422209000559?via%3Dihub

Wuang, Y.-P., & Su, C.-Y. (2009). Reliability and responsiveness of the Bruininks–Oseretsky Test of Motor Proficiency-in children with intellectual disability. *Research in Developmental Disabilities, 30*(5), 847-855. https://www.sciencedirect.com/science/article/abs/pii/S0891422208001777?via%3Dihub

Wuang, Y.-P., Su, J., & Su, C. (2012). Reliability and responsiveness of the Movement Assessment Battery for Children-Test in children with developmental coordination disorder. *Developmental medicine and child neurology, 54*(2), 160. https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/j.1469-8749.2011.04177.x?download=true

Xin, F., Chen, S.-T., Clark, C., Hong, J.-T., Liu, Y., & Cai, Y.-J. (2020). Relationship between Fundamental Movement Skills and Physical Activity in Preschool-aged Children: A Systematic Review. *International Journal of Environmental Research & Public Health, 17*(10), 3566.

Zhu, W., Fox, C., Park, Y., Fisette, J. L., Dyson, B., Graber, K. C., Avery, M., Franck, M., Placek, J. H., & Rink, J. (2011). Development and calibration of an item bank for PE metrics assessments: Standard 1. *Measurement in Physical Education and Exercise Science, 15*(2), 119-137.

Zimmer, R., & Volkamer, M. (1987). *Motoriktest für vier- bis sechsjärige Kinder (manual)*. Beltz Test.

Zoia, S., Biancotto, M., Guicciardi, M., Lecis, R., Lucidi, F., Pelamatti, G. M., Carrozzi, M., Skabar, A., Sugden, D. A., & Barnett, A. L. (2019). An evaluation of the Movement ABC-2 Test for use in Italy: A comparison of data from Italy and the UK. *Research in Developmental Disabilities, 84*, 43-56. https://www.sciencedirect.com/science/article/abs/pii/S0891422218300908?via%3Dihub

Žuvela, F., Božanić, A., & Miletić, Đ. (2011). POLYGON–A new fundamental movement skills test for 8 year old children: construction and validation. *Journal of sports science and medicine, 10*, 157-163.

Zysset, A. E., Kakebeeke, T. H., Messerli-Bürgy, N., Meyer, A. H., Stülb, K., Leeger-Aschmann, C. S., Schmutz, E. A., Arhab, A., Ferrazzini, V., & Kriemler, S. (2018). The validity of parental reports on motor skills performance level in preschool children: a comparison with a standardized motor test. *European Journal of Pediatrics, 177*(5), 715-722.

Appendix A

PROSPERO form for the Systematic Review in Chapter 2

Systematic review

To edit the record click *Start an update* below. This will create a new version of the record - the existing version will remain unchanged.

* Review title.

Give the title of the review in English

Evaluating the validity and reliability of assessment tools used to measure fundamental movement skill proficiency in children: a systematic review

Original language title.

For reviews in languages other than English, give the title in the original language. This will be displayed with the English language title.

* Anticipated or actual start date.

Give the date the systematic review started or is expected to start. 03/12/2018

* Anticipated completion date.

Give the date by which the review is expected to be completed. 01/11/2019

* Stage of review at time of this submission.

Tick the boxes to show which review tasks have been started and which have been completed. Update this field each time any amendments are made to a published record.

Reviews that have started data extraction (at the time of initial submission) are not eligible for inclusion in PROSPERO.

If there is later evidence that incorrect status and/or completion date has been supplied, the published PROSPERO record will be marked as retracted.

This field uses answers to initial screening questions. It cannot be edited until after registration. The review has not yet started: No

Review stageStarted Completed

Preliminary searches Yes Yes

Piloting of the study selection process Yes Yes

Formal screening of search results against eligibility criteria Yes Yes

Data extraction Yes Yes

Risk of bias (quality) assessment Yes Yes

Data analysis Yes Yes

Provide any other relevant information about the stage of the review here.

* Named contact.

The named contact is the guarantor for the accuracy of the information in the register record. This may be any member of the review team.

Lucy Eddy

Email salutation (e.g. "Dr Smith" or "Joanne") for correspondence: Miss Eddy

* Named contact email.

Give the electronic email address of the named contact. ps13lhe@leeds.ac.uk

Named contact address

PLEASE NOTE this information will be published in the PROSPERO record so please do not enter private information, i.e. personal home address

Give the full institutional/organisational postal address for the named contact.
School of Psychology, University of Leeds, LS2 9JT

Named contact phone number.

Give the telephone number for the named contact, including international dialling code.

+44(0)7802639723

* Organisational affiliation of the review.

Full title of the organisational affiliations for this review and website address if available. This field may be completed as 'None' if the review is not affiliated to any organisation.

University of Leeds (https://www.leeds.ac.uk/)

* Review team members and their organisational affiliations.

Give the personal details and the organisational affiliations of each member of the review team. Affiliation refers to groups or organisations to which review team members belong.

NOTE: email and country now MUST be entered for each person, unless you are amending a published record.

Miss Lucy Eddy. University of Leeds

Miss Nishaat Shahid. Bradford Institute for Health Research

Dr Daniel Bingham. Bradford Institute for Health Research

Dr Liam Hill. University of Leeds

Miss Kirsty Crossley. Bradford Institute for Health Research

Professor Mark Mon-Williams. University of Leeds

Miss Marsha Ellingham-Khan. Centre for Applied Education Research
Miss Ava Otteslev. Centre for Applied Education Research

Natalie Figueredo. Centre for Applied Education Research

* Funding sources/sponsors.

Details of the individuals, organizations, groups, companies or other legal entities who have funded or sponsored the review.

Lucy Eddy’s PhD is funded by the Economic and Social Research Council (ESRC).

* Conflicts of interest.

List actual or perceived conflicts of interest (financial or academic). None

Collaborators.

Give the name and affiliation of any individuals or organisations who are working on the review but who are not listed as review team members. NOTE: email and country must be completed for each person, unless you are amending a published record.

Professor Mark Mon-Williams. University of Leeds

* Review question.

State the review question(s) clearly and precisely. It may be appropriate to break very broad questions down into a series of related more specific questions. Questions may be framed or refined using PI(E)COS or similar where relevant.

To what extent have the validity and reliability of current measures of childhood fundamental movement skill proficiency been established?

* Searches.

State the sources that will be searched (e.g. Medline). Give the search dates, and any restrictions (e.g. language or publication date). Do NOT enter the full search strategy (it may be provided as a link or attachment below.)

PubMed, Ovid MEDLINE, Ovid Embase, EBSCO CINAHL, EBSCO SPORTDiscus, Ovid PsycINFO and Web of Science will be searched. The search strategy will comprise of terms which relate to or describe the question of interest. Papers not captured by searching these databases will be identified by reading through the reference lists of included studies. Before a final synthesis of results, the searches will be re-run to identify any further studies that need to be included. Publications will only be included if they are written in English, unless a translated version is available.

URL to search strategy.

Upload a file with your search strategy, or an example of a search strategy for a specific database, (including the keywords) in pdf or word format. In doing so you are consenting to the file being made publicly accessible.

Or provide a URL or link to the strategy. Do NOT provide links to your search results.

https://www.crd.york.ac.uk/PROSPEROFILES/121029_STRATEGY_20190103.pdf

Yes I give permission for this file to be made publicly available

* Condition or domain being studied.

Give a short description of the disease, condition or healthcare domain being studied in your systematic review.

Fundamental Movement Skills (FMS) are a group of foundational motor skills, which provide the basis for the development of more complex movements and enable participation in a wide range of physical activity (Logan, Ross, Chee, Stodden, & Robinson, 2018). There is a growing body of research exploring the effects of FMS competence on other aspects of childhood development, with evidence suggesting that these skills may have wide-reaching secondary impacts (Barnett et al., 2016) including cognition (Haapala, 2013) and academic achievement (Jaakkola, Hillman, Kalaja, Liukkonen, 2015). There are a large proportion of children who are not competent at performing FMS in the UK (Foulkes et al., 2015) and worldwide (Mukherjee, Ting & Fong, 2017). However, there are a large number of assessment tools used to assess fundamental movement skills in children, and it is unclear how valid and reliable these assessment tools are. This systematic review will, therefore, explore the validity and reliability of assessments of childhood fundamental movement skills.

* Participants/population.

Specify the participants or populations being studied in the review. The preferred format includes details of both inclusion and exclusion criteria.

Studies will be included if they include participants who are of school age (both primary and secondary) in the country in which they reside. Children who are too young to attend school will be excluded. There will be no health or motor skill ability criteria applied, however this information will be extracted during full text review to explore whether demographic factors may have an influence on the validity and reliability of assessment tools. Assessment tools of perceived motor competence, rather than actual motor competence will be excluded from the review.

* Intervention(s), exposure(s).

Give full and clear descriptions or definitions of the interventions or the exposures to be reviewed. The preferred format includes details of both inclusion and exclusion criteria.

A pre-review search was completed to identify assessment tools used to measure childhood fundamental movement skills (FMS) using the search terms ‘fundamental movement skills’ OR ‘fundamental motor skills’ in the databases identified for the systematic review. Any studies which explicitly stated they were measuring FMS using an assessment tool were included.

Studies will be included if they use one of 32 assessment tools identified

The review will evaluate the evidence for the validity and reliability of these tools. Assessments which have not had the validity or reliability explored will be included for narrative purposes.

* Comparator(s)/control.

Where relevant, give details of the alternatives against which the intervention/exposure will be compared (e.g. another intervention or a non-exposed control group). The preferred format includes details of both inclusion and exclusion criteria.

Not applicable

* Types of study to be included.

Give details of the study designs (e.g. RCT) that are eligible for inclusion in the review. The preferred format includes both inclusion and exclusion criteria. If there are no restrictions on the types of study, this should be stated.

Any study which explores the validity and reliability of assessment tools used to measure fundamental movement skills that can be quantified using statistical tests will be included.

Context.

Give summary details of the setting or other relevant characteristics, which help define the inclusion or exclusion criteria. Assessment tools of perceived motor competence, rather than actual motor competence will be excluded from the review.

* Main outcome(s).

Give the pre-specified main (most important) outcomes of the review, including details of how the outcome is defined and measured and when these measurement are made, if these are part of the review inclusion criteria.

Any form of validity or reliability that can be quantified statistically (e.g. concurrent validity, predictive validity, test-retest reliability, inter-rater reliability, etc.)

* Additional outcome(s).

List the pre-specified additional outcomes of the review, with a similar level of detail to that required for main outcomes. Where there are no additional outcomes please state 'None' or 'Not applicable' as appropriate to the review

None.

* Data extraction (selection and coding).

Describe how studies will be selected for inclusion. State what data will be extracted or obtained. State how this will be done and recorded.

Titles and abstracts identified using the search strategy will be screened independently by three reviewers to identify studies that may qualify for inclusion. Reviewers will not be blind to information regarding the author or the journal the article is published in. The full text of potentially eligible studies will be retrieved and independently assessed for eligibility by three review team members. Disagreement between reviewers over eligibility will be resolved through consultation with a fourth reviewer.

Three review authors, not blinded to information regarding the author or the journal will independently extract information from a third of the studies. Information will be extracted on the following aspects of each study:

Study eligibility, study design, study context, date of publication, region/country, participant demographic/socioeconomic characteristics, who implemented the assessment tool, as well as information to allow assessment of study risk of bias.

The types of validity and reliability measured by each study and the statistics used to measure these constructs

Statistical findings and reported conclusions

Source(s) of research funding and potential conflicts of interest.

* Risk of bias (quality) assessment.

State which characteristics of the studies will be assessed and/or any formal risk of bias/quality assessment tools that will be used.

Risk of bias will be assessed independently by three reviewers using the RoBANS tool for non-randomized studies (Kim et al., 2013). Each of the three reviewers will complete risk of bias assessment for a third of the studies. The lead reviewer will check all judgements, and if disagreements occur, a fourth reviewer will be consulted.

* Strategy for data synthesis.

Describe the methods you plan to use to synthesise data. This must not be generic text but should be specific to your review and describe how the proposed approach will be applied to your data.

If meta-analysis is planned, describe the models to be used, methods to explore statistical heterogeneity, and software package to be used.

Summary tables of each FMS assessment tool will be created to detail the studies that have explored the validity and reliability of each tool, demographic information about the samples, who implemented the assessment tool (e.g. researcher, teacher etc), the different forms of reliability and validity assessed (e.g. internal consistency, re-test reliability, criterion and construct validity) statistical values (e.g. intraclass correlation values, mean differences and Pearson's *r*), and the quality of each paper. Two reviewers will independently assess the quality of each paper using the RoBANS tool, with any discrepancies being resolved through discussion with a third reviewer.

If the design of studies are sufficiently homogenous, a meta-analysis comparing the assessment tools across the different forms of validity and reliability will be conducted in RevMan using aggregate data (e.g. comparing the test-retest reliability of the different assessment tools). The statistical values from each included paper will be extracted independently by two reviewers. Any discrepancies will be resolved through consultation with a third reviewer. This analysis will, however, only be possible if validity and reliability are measured in similar ways across multiple papers for each assessment tool. If a meta- analysis is not possible, narrative synthesis will be used.

* Analysis of subgroups or subsets.

State any planned investigation of ‘subgroups’. Be clear and specific about which type of study or participant will be included in each group or covariate investigated. State the planned analytic approach.

None planned

Wounds, injuries and accidents No

Violence and abuse No

Language.

Select each language individually to add it to the list below, use the bin icon to remove any added in error.

English

There is not an English language summary

* Country.

Select the country in which the review is being carried out. For multi-national collaborations select all the countries involved.

England

Other registration details.

Name any other organisation where the systematic review title or protocol is registered (e.g. Campbell, or The Joanna Briggs Institute) together with any unique identification number assigned by them.

If extracted data will be stored and made available through a repository such as the Systematic Review Data Repository (SRDR), details and a link should be included here. If none, leave blank.

Reference and/or URL for published protocol.

If the protocol for this review is published provide details (authors, title and journal details, preferably in Vancouver format)

No I do not make this file publicly available until the review is complete

Dissemination plans.

Do you intend to publish the review on completion?

Yes

The review will be submitted to a journal upon completion. The results of the systematic review will also be documented within a PhD thesis.

Keywords.

Give words or phrases that best describe the review. Separate keywords with a semicolon or new line. Keywords help PROSPERO users find your review (keywords do not appear in the public record but are included in searches). Be as specific and precise as possible. Avoid acronyms and abbreviations unless these are in wide use.

Fundamental movement skills

Validity

Reliability

Assessment

Details of any existing review of the same topic by the same authors.

If you are registering an update of an existing review give details of the earlier versions and include a full bibliographic reference, if available.

* Current review status.

Update review status when the review is completed and when it is published.

New registrations must be ongoing so this field is not editable for initial submission.

Review_Completed_published

Any additional information.

Provide any other information relevant to the registration of this review.

There is a similar systematic review looking at the validity and reliability of motor skill assessments. This review is however, substantially different as it focuses on one specific group of motor skills (fundamental movement skills). Also, this review does not limit to typically developing children, and can therefore explore how well assessment tools can discriminate between typically developing and non-typically developing children.

Details of final report/publication(s) or preprints if available.

Leave empty until publication details are available OR you have a link to a preprint (NOTE: this field is not editable for initial submission).

List authors, title and journal details preferably in Vancouver format.

Eddy, L. H., Bingham, D. D., Crossley, K. L., Shahid, N. F., Ellingham-Khan, M., Otteslev, A., Figueredo, N. S., Mon-Williams, M., & Hill, L. J. B. (2020). The validity and reliability of observational assessment tools available to measure fundamental movement skills in school-age children: A systematic review. PloS One, 15(8), e0237919. https://doi.org/10.1371/journal.pone.0237919

https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0237919

Appendix B

Search Strategy for the Systematic Review in Chapter 2

Assessment tools terms	**Reliability/ validity search terms**	**Population search terms**
Movement Assessment Battery for Children	Valid*	Child*
MABC	Reliab*	Infant*
MABC 2	Accura*	School child*
MABC 2	Feasib*	Adolescen*
M-ABC	Consisten*	Preschool
Movement-ABC	Agreement	Pre-school
Movement-ABC 2	Precision	Boy*
Movement-ABC-2	Psychometric propert*	Girl*
Movement ABC	Repeatab*	Young people
Movement ABC 2	Reproducib*	Teenager
Movement ABC-2	Convergent	Youth
Assessment of Perceptual and Fundamental Motor Skills Inventory	divergent	
APM Inventory		
APM-Inventory		
Fundamental Motor Skills Test Package		

FMS Test Package		
Fundamental Movement Skill Polygon		
FMS Polygon		
FMS-Polygon		
Peabody Developmental Motor Scale		
PDMS		
PDMS 2		
PDMS-2		
Get Skilled Get Active		
GSGA		
NSW Department of Education and Training resource on FMS		
New South Wales Department of Education and Training resource on FMS		
NSW Department of Education and Training resource on Fundamental Movement Skills		
New South Wales Department of Education and Training resource on Fundamental Movement Skills		

Körperkoordinationstest für Kinder		
Korperkoordinationstest fur kinder		
KTK		
Test of Gross Motor Development		
TGMD		
TGMD 2		
TGMD-2		
TGMD 3		
TGMD-3		
Bruninks-Oseretsky Test of Motor Proficiency		
BOTMP		
BOTMP 2		
BOTMP-2		
BOT		
BOT-2		
BOT 2		
Furtado-Gallagher Computerized Observational Movement Pattern Assessment System		
FG-COMPASS		

Motoriktest für vier-bis sechsjährige Kinder		
Motoriktest fur vier-bis sechsjahrige Kinder		
MOT 4-6		
Ohio State University Scale of Intra Gross Motor Assessment		
OSU-SIGMA		
SIGMA		
Athletic Skills Track		
AST		
Canadian Agility and Movement Skill Assessment		
CAMSA		
Children's Activity and Movement in Preschool Motor Skills Protocol		
CMSP		
CHAMPS		
CHAMPS motor skills protocol		
Early years movement skills checklist		
EYMSC		
Fundamental Motor Skill Stage Characteristics		

Fundamental Movement Screen		
Fundamental Movement Screen Test		
Fundamental movement skill assessment tool		
Instrument for the Evaluation of Fundamental Movement Patterns		
Instrumento de Evaluacion de los Patrones Basicos de Movimiento		
IPBM		
Lifelong Physical Activity Skills Battery		
NSW Schools Physical Activity and Nutrition Survey		
New South Wales Schools Physical Activity and Nutrition Survey		
NSW SPANS		
New South Wales SPANS		
Objectives-Based Motor Skill Assessment Instrument		
Passport for Life		
PE Metrics		

PLAYbasic		
PLAYfun		
Preschooler gross motor quality scale		
PGMQ		
Smart Start		
Smart start-2		
Smart Start 2		
Teen Risk Screen		
Test for FMS in Adults		
Test for Fundamental Movement Skills in Adults		
TFMSA		
Instrumento para la evaluacion de Patrones Basicos de Movimiento		
IPBM		
Victorian FMS Assessment instrument		
Victorian Fundamental Movement Skills Assessment Instrument		
Victorian FMS Teacher* Manual Assessment		

Victorian Fundamental Movement Skill Teacher* Manual Assessment		
Victorian Fundamental Motor Skills manual		
Department of Education of Victoria A Fundamental Motor Skills: A Manual for Classroom Teachers		
Western Australian Stay in Step Screening Assessment		
Western Australian Department of Education Steps Resource: The Stay in Step Screening Assessment		
Stay in step		

Appendix C

Study Table for the Systematic Review in Chapter 2

Citation	**Assessment tool(s) used**	**Sample**	**Outcome**	**Statistics used**	**Results**	**Methodology quality rating (%)**
Africa & Kidd (2013)	Teen risk screen	Girls = 125 (mean age = 12.12; SD= 1.1) Teachers = 7	Internal Consistency	Cronbach's alpha	Posture and stability (axial movement) time 1 = .93, time 2 = .86 Posture and stability (dynamic movement) time 1 = .89, time 2 = .86 Locomotor (single skills) time 1 = .89, time 2 = .90 Locomotor (combination) time 1= .67, time 2 = .56 Manipulative Skills (sending away) time 1 = .71, time 2 = .45 Manipulative skills (maintaining possession) = .58	**36%**

			Test-retest reliability	Pearson correlation	Posture and stability (axial movement) = .59 Posture and stability (dynamic movement) = .69 Locomotor (single skills) = .88 Locomotor (combination) = .76 Manipulative Skills (sending away) = .43 Manipulative skills (maintaining possession) = .58	
				Intraclass correlation	Posture and stability (axial movement) = .51 (.32, .65) Posture and stability (dynamic movement) = .63 (.46, .75) Locomotor (single skills) = .86 (.76, .91) Locomotor (combination) = .74 (.65, .82)	

					Manipulative Skills (sending away) = .34 (.13, .51) Manipulative skills (maintaining possession) = .56 (.42, .67)	
			Structural validity	Confirmatory Factor analysis	Postural stability (axial movement) and postural stability (dynamic movement) test 1 scales - marginal fit statistics with the RMSEA just outside the prescribed boundaries (<.05). AGFA indices were acceptable (>.95). Test 2 fit statistics were well below acceptable. Locomotor (single skills) - marginally acceptable RMSEA (Test 1 and 2) and acceptable AGFI, CR and VE (Test 1 and 2). 3-scale CFA model gave acceptable results for all indices at both time points with perhaps the VE of manipulative skills (sending away) at time Test 2 being slightly lower (VE=0.43).	

Allen et al. (2017)	TGMD-3	14 children with ASD (age range 4-10) 21 typically developing children, aged 4 - 11.	Internal consistency	Cronbach's alpha	TGMD-3 Typically developing group: Locomotor skills= 0.70; Ball Skills= 0.6; Overall= 0.74 ASD- traditional protocol: Locomotor skills= 0.82; Ball Skills= 0.75; Overall= 0.88 ASD- visual protocol: Locomotor skills= 0.93; Ball skills= 0.81; Overall= 0.93 TGMD-2 Locomotor= 0.85; Ball skills= 0.88; Overall= 0.91	**55%**
			Inter-rater reliability	Intra-class correlational coefficient with 95% confidence limits	ASD visual: Locomotor= 0.98 (0.94, 1.00) Ball skills= 0.96 (0.86, 0.99)	

					Overall= 0.99 (.95, 1.00) ASD traditional: Locomotor= 0.98 (0.92, 0.99) Ball skills= 0.97 (0.91, 0.99) Overall= 0.98 (0.94, 1.00) Typically developing: Locomotor= 0.91 (0.79, 0.96) Ball skills= 0.92 (0.81, 0.97) Overall= 0.94 (0.87, 0.98)	
			Intra-rater reliability		ASD visual: Locomotor= 0.99 (.95, 1.00) Ball skills= 1.00 (0.98, 1.00)	

					Overall= 0.99 (0.98, 1.00) ASD traditional: Locomotor= 0.97 (0.88, 0.99) Ball skills= 0.99 (0.96, 1.00) Overall= 0.99 (0.92, 1.00) Typically developing: Locomotor= 0.97 (0.93, 0.99) Ball skills= 0.91 (0.68, 0.97) Overall= 0.95 (0.84, 0.98)	
			Test-retest reliability		ASD visual: Locomotor= 0.92 (0.65, 0.98)	

					Ball skills= 0.83 (0.39, 0.96) Overall= 0.92 (0.66, 0.98) ASD traditional: Locomotor= 0.92 (0.65, 0.98) Ball skills= 0.82 (0.31, 0.96) Overall= 0.91 (0.63, 0.98) Typically developing: Locomotor= 0.81 (0.94, 0.53) Ball skills= 0.84 (0.62, 0.94) Overall= 0.92 (0.78, 0.97)	
			Structural validity	Two-tailed independent t-test	Differences between TGMD-3 traditional protocol (typically developing and ASD):	

					Locomotor - *t*=3.75, *p*=.001 Ball Skills - *t*=3.51, *p*=.002 Overall - *t*=3.93, *p*=.001 typically developing group scored significantly higher on the TGMD-3 traditional protocol than the ASD group Positive correlations between TGMD-3 traditional protocol and the TGMD-3 visual protocol scores: Locomotor - *r*(10)=0.94, *p*<0.001, 95% CI (0.80, 0.98) Ball Skills - *r*(10)=0.93, *p*<0.001, 95% CI (0.76, 0.98) Overall - *r*(10)=0.96, *p* < 0.001, 95% CI (0.86, 0.99).	

Bakke et al (2017)	MABC- 2 Portuguese version	Children= 30 (17 boys; 13 girls; mean age = 9.44; SD= 1.08) Moderate low vision= 28 Severe low vision= 2	Test-retest reliability	Intraclass correlational coefficient with 95% confidence limits	A1xA2 (rater 1 in the first application; rater 1 in the second application) Aiming and catching= 0.867 (0.676, 0.945) Balancing = 0.856 (0.651, 0.941) Total= 0.958 (0.899, 0.983) B1xB2 (rater 2 in the first application; rater 2 in the second application) Aiming and catching= 0.847 (0.628, 0.936) Balancing= 0.834 (0.596, 0.931)	**50%**

			Inter-rater reliability	Intraclass correlational coefficient with 95% confidence limits	A1xB2 (rater 1 in the first application; rater 2 in the first application) Aiming and catching= 0.957 (0.905, 0.980) Balance= 0.936 (0.867, 0.970) Total= 0.971 (0.939, 0.986)	
			Internal consistency	Cronbach's alpha	Cronbach's alpha ranged from 0.790 to 0.868.	
Bardid et al (2016)	KTK MOT 4-6	638 young children (323 boys; 315 girls) aged 5-6.	Concurrent Validity Hypothesis Testing Validity	Spearman's rank	KTK MQ and MOT 4-6 MQ (*r*s = .63) KTK MQ and MOT 4-6 gross motor cluster score (*r*s = .62) KTK MQ and MOT 4-6 locomotor score (*r*s = .56)	**47%**

					KTK MQ and MOT 4-6 stability score (*r*s = .43) KTK MQ and MOT 4-6 object-control score (*r*s = .37). KTK MQ and MOT 4-6 ne motor cluster score (*r*s = .32). MQs of both tests (*r*s = .61–.67) KTK MQ and MOT 4-6 gross motor score (*r*s = .62–.72). KTK MQ and MOT 4-6 locomotor score (*r*s = .53–.68) KTK MQ and MOT 4-6 stability score (*r*s = .42–.49) KTK MQ and MOT 4-6 object-control score (*r*s = .31–.44)	

					KTK MQ and MOT 4-6 ne motor cluster score (*r*s = .20–.47).	
				Cohen's Kappa	KTK and MOT 4-6 at P2 (.50) P16 (.52), P84 (.23), P98 (.00).	
Bardid et al. 2016b	TGMD-2	1614 children aged 3-8 years 841 boys, 773 girls	Cross cultural validity	Chi-squared	Belgian children performed significantly worse than US norm sample on GMQ (chi-square = 219.548, $p < 0.001$, Cramer's V = 0.279). Belgian children's performed worse on the locomotor (chi-square = 147.872, $p < 0.001$, Cramer's V = 0.229) and object control subtests (chi-square = 357.94, $p < 0.001$, Cramer's V = 0.356)	**60%**

			Hypotheses testing validity	T-tests	No significant differences between Belgian and US boys on the locomotor subtest in the age groups of three (t = 0.961, p = 0.338), four (t= 1.735, p = 0.084) and five (t = 1.300, p = 0.195) No significant difference between Belgian and US three year-old girls (t = -0.828, p = 0.410) and four-year-old girls (t = 1.233, p = 0.220), Five year-old Belgian girls scored significantly higher on locomotor skills (t = 4.813, p < 0.001, Cohen's d = 0.4). Lower locomotor skill performances for Belgian boys and girls aged six years (boys t = -5,632, p < 0.001, Cohen's d = 0.446 and girls t = -2.193, p = 0.030, Cohen's d = 0.161), seven years (boys t = -4.036, p < 0.001, Cohen's d = 0.396 and girls t = -3.106, p = 0.002, Cohen's d = 0.306) and eight years (boys t = -3.577, p = 0.001, Cohen's d = 0.453 and girls t = -9.717, p < 0.001, Cohen's d = 1.095)	

					Belgian children of all age groups performed significantly worse on object control skills than the US reference population (all p-values < 0.001, Cohen's d = 0.303-1.269).	
Bardid, Utesch, & Lenoir (2019)	BOT-2 SF	2538 children aged 6-11 years from urban and rural areas.	Structural Validity	Rasch Analysis – General Partial Credit Model	No global model fit (not unidimensional) Copying a square and copying a star were misfitting After removing misfitting items, BOT-2 SF was unidimensional ($19.92 \leq \chi 2 \leq 60.71$; $0.06 \leq P \leq .97$ Disordered thresholds for all items except item 5 Good sensitivity and reliability across the continuum of motor competence for 6- to 8-year-old children, 9-11 year olds showed ceiling effects	**48%**
Barnett et al. (2014)	TGMD-2	37 children (65% girls) aged 4–8 years (M = 6.2, SD = 0.8)	Inter-rater reliability	Intraclass Correlation	Stationary dribble: Contacts ball with one hand at about belt level k1=0.83 k2=0.71 Pushes ball with fingertips (not a slap) k1= 0.62 k2=0.63	**54%**

					Ball contacts surface in front of or to the outside of preferred foot k1=0.94, k2=0.87 Maintains control of ball for four consecutive bounces without having to move the feet to retrieve it – k1=0.75 k2= 0.87 Striking a stationary ball: Dominant hand grips bat above nondominant hand k1= 0.92 k2=0.91 Nonpreferred side of body faces the imaginary tosser with feet parallel – k1=0.38 k2=1.00 Hip and shoulder rotation during swing k1=0.27 k2= 0.32 Pronounced/clear transfer of body weight to front foot k1=0.68 k2= 0.61	

					Bat contacts ball k1= 0.88 k2=0.69 Overhand throw: Windup is initiated with downward movement of hand/arm k1= 0.34 k2= 0.39 Rotates hip and shoulders to a point where the nonthrowing side faces the wall k1=0.50 k2= 0.53 Weight is transferred by stepping with the foot opposite the throwing hand k1=0.42 k2= 0.62 Follow-through beyond ball release diagonally across the body and down towards the non-preferred side k1=0.65 k2= 0.65 Underhand roll	

					Preferred hand swings down and back, reaching behind the trunk while chest faces cones k1=0.84 k2=0.87 Strides forward with foot opposite the preferred hand towards the cones k1= 0.62 k2= 0.72 Bends knees to lower body k1=0.72 k2=0.49 Releases ball close to the floor so ball does not bounce more than 4 inches high k1=0.59 k2= 0.47 Kick An elongated stride or leap immediately prior to ball contact k1= 0.84 k2=0.36 Nonkicking foot placed even with or slightly in back of the ball k1=0.69 k2= 0.65	

					Kicks ball with instep of preferred foot (shoe-laces) or toe k1=1.00 k2=1.00 Catch Preparation phase where hands are in front of the body and elbows are flexed k1=0.37 k2= 0.54 Arms extend while reaching for the ball as it arrives k1=0.42 k2= 0.53 Ball is caught by hands only k1= 0.89 k2=0.81	
				Intraclass correlation	Object control subset= excellent (0.93) Dribble = 0.94 (0.89-0.97) Strike= 0.85 (0.73-0.92) Throw= 0.84 (0.70-0.91) Roll= 0.82 (0.67-0.90)	

					Kick= 0.80 (0.64-0.89) Catch= 0.71 (0.54-0.84)	
Borremans et al (2009)	MABC- 2	30 young adults aged 15–21 years (21 males; 9 females; mean age = 17.2; SD = 1.2) with Asperger syndrome Control group = 30 young adults (mean age= 16.9; SD = 0.8yrs)	Internal consistency	Cronbach's Alpha	Manual dexterity= .44 (in both groups) If bimanual task deleted= .65 for control group; .71 for AS group Ball skills = .73 (control) .84 (AS group) Balance = .35 (control group) .57 (AS) Zigzag hopping items deleted =.73.	**63%**

			Hypothesis testing validity	MANOVA	AS performed statistically lower compared to control on overall motor competence (Wilk's Lambda = .49, $F(11, 48) = 4.48$ ($p < .001$), manual dexterity, $\lambda = .72$, $F(4, 55) = 5.29$ ($p < .001$), ball skill items $\lambda = .63$, $F(3, 56) = 11.06$ ($p < .001$); and for balance items $\lambda = .65$, $F(4, 55) = 7.34$ ($p < .001$).	
Brian et al. (2018)	TGMD-2 and TGMD-3	66 children and adolescents (boys = 41; girls = 25) aged 9–18 years (mean age = 12.93, SD = 2.40 years) White = 51; Black = 9;	Inter-rater reliability	Intra-class correlation	TGMD-3: Gross motor scale= ICC = .91; CI [.85, .94]), Locomotor= ICC = .92; CI [.87, .95 Ball skills scales = (ICC = .92; CI [.87, .95])	**44%**
			Internal consistency	McDonald's omega and gauge reliability	TGMD-3 Gross motor (ω = .95; , CI, [.93, .96]) Ball skills subscale (ω = .91; CI [.87, .94]) Locomotor subscales (ω = .89; CI [.84, .93])	

		Asian = 2; Hispanic = 4 Mean body mass index of 21.78 (SD = 5.85; boys = 22.09, SD = 6.36; girls = 21.32, SD = 5.07).				
			Structural Validity	Confirmatory factor analysis Pearson product moment correlations	Correlations ranged from r = .98–.99 (all significant) Factor loadings ranged from .57 to .92. Ball skill and locomotor subscales= (.89)	
			Criterion Validity (Concurrent)	Pearson product moment correlations	Object control TGMD-2 & ball skills TGMD-3= .98 Object control TGMD-2 & Locomotor TMGD-2 = .84 Object control TGMD-2 & Locomotor TMGD-3 = .87 Object control TGMD-2 & Gross Motor TGMD-2 = .96 Object control TGMD-2 & Gross Motor TGMD-3 = .96 Ball skills TGMD-3 & Locomotor TGMD-2 = .86	

					Ball skills TGMD-3 & Locomotor TGMD-3 = .9 Ball skills TGMD-3 & Gross Motor TGMD-2 = .96 Ball skills TGMD-3 & Gross Motor TGMD-3 = .98 Locomotor TGMD-2 & Locomotor TGMD-3 = .98 Locomotor TGMD-2 & Gross Motor TGMD-2 = .96 Locomotor TGMD-2 & Gross Motor TGMD-3 = .94 Locomotor TGMD-3 & Gross Motor TGMD-2 = .96 Locomotor TGMD-3 & Gross Motor TGMD-3 = .97 Gross Motor TGMD-2 & Gross Motor TGMD-3 = .99	
Brown (2019)	BOT-2-BF	123 children aged 8-12 (67 males & 56	Structural Validity	Rasch Measureme	14 item BOT-BF:	**60%**

		females; mean age=10 years, 2 months; SD=1 year, 4 months)		nt Model Analysis	Bilateral Coordination item 3 (BC3), Bilateral Coordination item 6 (BC6), Balance item 2 (B2), Fine Motor Integration item 7 (FMI7), Strength item 2 (S2), Upper-limb Coordination item 1 (UC1), Fine Motor Integration item 2 (FMI2), Manual Dexterity item 2 (MD2), and Fine Motor Precision item 3 (FMP3) were misfitting items BOT-2 BF was unidimensional DIF was found for balance item 7 when examining gender differences Person-separation reliability was 0.63, and item-separation reliability was 1.00 The Person Raw Score reliability for the BOT-2-BF was 0.69	

					Revised 5 item BOT-2 BF (nine misfitting items removed) No misfitting items No items had DIF based on gender Unidimensionality requirements were met Person-separation reliability = 0.60, and item separation reliability =1.00 Person Raw Score reliability = 0.62.	
Brown (2019b)	BOT-2	117 children aged between 8 and 12 years of age - mean age of	Structural Validity	Rasch Analysis	Item Fit – logit scores for the eight BOT-2 subscale items ranged from −9.36 to 7.46. Upper limb coordination had one misfitting item. Balance had 4 misfitting items. FMCC and BCC both had a large number of items that didn't meet Rasch requirements	**93%**

		10 years 2 months 65 males (56.6%) and 52 females (44.4%)			Unidimensionality - The percentage of unexplained variance in the eight BOT-2 subscales ranged from 0.00% to 4.70%. Subscales are unidimensional. The percentage unexplained for composite scales ranged from .9% - 2%, and are unidimensional DIF- balance and upper limb coordination had one item which exhibited DIF by gender. MCC and BCC had 2 items with gender DIF. Reliability - Item reliability of the eight BOT-2 subscales ranged from 0.95 to 1.00 while person reliability coefficients ranged from 0.08 to 0.80. For the four composite scales, item reliability coefficients ranged from 0.98 to 1.00 and person reliability coefficients ranged from 0.50 to 0.85.	
Cairney et al. (2009)	BOT-SF MABC	BOT-SF = 2058 children 24 of 128 children aged 10 (n = 10), 11 (n = 10) or	Concurrent validity	PPV; 5th and 15th percentile cut-points on the M-ABC	21 of 24 children identified as probable DCD on the BOT-SF were below the 15th percentile on M-ABC - PPV = 0.88 (95% CI = 0.69 to 0.96).	**30%**

		12 (n = 4) scoring below the sixth percentile = MABC			15 children were below the 5th percentile – PPV= 0.63 (95% CI = 0.43 to 0.79)	
Cairney et al (2018)	PLAYfun	215 children in total: 112 (52%) males and 103 (48%) females. Age was not recorded for one child. For the remaining 214, the average age was 10.3 years (SD=1.7), with a minimum of 6.5 and a maximum of 14.1.	Reliability / Measurement Error (Inter-rater reliability)	Intra-class correlation (ICC)	For the total score among 7 assessors in the pilot sample of 10 children: ICC = 0.87	**76%**
			Structural Validity Hypothesis testing validity	Confirmatory factor analysis	The fit of the initial model was fair (RMSEA = 0.065, 90% CI = 0.052 to 0.077; CFI =0.93; TLI = 0.91). Modification - a path to allow error terms for tasks 15 and 16. RMSEA = 0.055, 90% CI = .03 - .075, CFI = .95, TLI = .94.	

Cano-Cappellacci,Leyton and Carreno (2015)	TGMD-2 Chilean Version TGMD-2	92 children aged 5-10 (56 boys; 36 girls; mean age=7.5; SD=1.6)	Content Validity	Content validity index (CVI)	Language clarity - CVI = 0.88 for TGMD-2-CH - CVI = 0.83 for the modified TGMD-2 TGMD-2-CH CVI = 0.90 Modified test CVI = 0.84	**41%**
			Inter-Rater Reliability	T-Test	Total score - *p*=.006 Locomotor – *p*=.14 Object Control – *p*=.01	
				CVI (95% CI)	Total score - 0.86 (0.72,0.93) Locomotor - 0.87 (0.73,0.93) Object Control - 0.88 (0.77,0.94)	
				T-Test	Total score - *p*=.91	

			Intra-Rater Reliability		Locomotor – *p*=.92 Object Control – *p*=.86	
				CVI (95% CI)	Total score - 0.91 (0.83, 0.95) Locomotor - 0.92 (0.83, 0.95) Object Control - 0.86 (0.76, 0.93)	
			Test-Retest Reliability	T-Test	Total score - *p*=.88 Locomotor – *p*=.86 Object Control – *p*=.80	
				CVI (95% CI)	Total score - 0.88 (0.75, 0.94) Locomotor - 0.86 (0.71, 0.93) Object Control - 0.80 (0.59, 0.90)	

Capio, Eguia and Simons (2016)	TGMD-2	81 children with intellectual disability aged 5-14 (65 boys; 16 girls; mean age = 9.29; SD= 2.71 years)	Intra-rater Reliability	Intra-class correlation	Locomotor= 0.995; (0.978-0.999) Object control= .998 (0.991-0.999) Total FMS= 0.997 (0.989-0.999)	**56%**
			Inter-rater reliability	Intra-class correlation	Locomotor= 0.996 (0.984- 0.999) Object control= 0.998 (0.992-1.000) Total FMS= 0.998 (0.991-0.999)	
			Internal consistency	Cronbach's alpha	Locomotor components = 0.830; range of 0.757–0.814 when each item is deleted. Object control components= 0.792; range of 0.713–0.757 when each item is deleted. Item-total correlation coefficients = locomotor components = 0.712 to 0.913, Object control components = 0.673 to 0.816.	
			Content Validity	Pearson product–moment	Age and locomotor = (r = 0.222, P = 0.047) and object control skills (r = 0.356, P = 0.001).	

				correlation coefficient		
				Multivariate analysis of covariance (ANCOVA)	Multivariate ANCOVA = (F(2, 78) = 5.865, P = 0.004, η2 = 0.131).	
			Structural validity	Confirmatory factor analysis (CFA) Hypothesis testing validity	Locomotor and object control of TGMD-2 with fit indices: χ2 = 33.525, DF = 34, P = 0.491, χ2/DF = 0.986 GFI = 0.931. RMSEA = 0.000 with 90% CI of 0.000–0.080	
Capio, Sit and Abernethy (2011)	TGMD-2	30 children with CP (17 girls, 13 boys) aged 6-14 (mean age= 9.83 years, SD = 2.5 years).	Inter-rater reliability	Cohen's Kappa coefficient	Kappa ranged from 0.875 – 0.907	**47%**

Chow et al. (2002)	Age Band IV of the MABC test	31 teenagers (mean age = 13.92, SD= 1.26)	Test- retest reliability	Intraclass correlation coefficient (ICC)	One-hand catch – preferred hand = 0.75 One-hand catch – non-preferred hand = 0.84 Throwing at wall target = 0.76 Two-board balance = 0.73 Cross board balance = 0.91 Jumping and clapping = 0.84 Zig-zag hopping – preferred leg = 0.91 Zig-zag hopping – non-preferred leg = 0.89 Walking backwards =0.06	**48%**
			Inter-rater reliability	Intraclass correlation coefficient (ICC)	One-hand catch – preferred hand =0.98 One-hand catch – non-preferred hand =0.97	

					Throwing at wall target = 0.92 Two-board balance = 1.00 Cross board balance =0.98 Jumping and clapping = 0.52 Zig-zag hopping – preferred leg =0.96 Zig-zag hopping – non-preferred = 0.96 Walking backwards = 0.95	
Crawford, Willson and Dewey (2001)	BOT & M-ABC	101 children with DCD (61 boys; 40 girls; mean age= 11.62 yrs; SD = 1.97) (low SES=25.8%;	Criterion Validity (Concurrent)	Observed agreement between tests (Po) and agreement corrected for by	BOT (gross motor) = PO= 0.846, Kappa= 0.673 BOT (fine motor) and BOT (battery composite) = PO= 0.791, Kappa= 0.476 BOT (fine motor) and BOT (gross motor) = PO= 0.667, Kappa= 0.264	**50%**

		middle SES= 47.3%; high SES= 26.9%) and 101 matched children in the non DCD group (81 boys; 20 girls; mean age= 11.50; SD= 2.00) (low SES= 22.1%; middle SES= 51.6%; high SES= 26.3%)		chance (kappa)	M-ABC and BOT battery composite = PO= 0.722, Kappa= 0.416 M-ABC and BOT Gross Motor= PO= 0.722, Kappa= .430 M-ABC and BOT Fine Motor= PO= 0.569, Kappa= 0.073	
Croce, Horvat and McCarthy (2001)	MABC, Bruininks-Oseretsky test	106 children aged 5-12 (39 girls; 67 boys)	Criterion Validity (Concurrent)	Pearson correlation coefficients	MABC test- Bruininks-Oseretsky Long From All groups= .76 5-6yr olds= .77 7-8yr olds= .76 9-10yr olds= .70 11-12 yr olds= .90	**40%**

					MABC - Bruininks-Oseretsky Short Form All groups= .71, 5-6yr olds= .79 7-8yr olds= .76 9-10yr olds= .60 11-12 yr olds= .90	
			Test-retest reliability of the MABC	Intraclass correlation coefficient (ICC)	All groups= .95 5-6 yr olds= .98 7-8yr olds= .95 9-10yr= .92 11-12yr= .97	
Darsaklis et al. (2013)	M-ABC-2 and BOT	Not specified	Inter-rater reliability	Cohen's kappa	MABC (overall) = κ = 0.93 BOT: Running speed and agility= k= 1.00 Balance= k=1.00	**13%**

					Bilateral coordination= k=1.00 Strength= k=1.00 Upper-limb coordination = k = 1.00	
Dos Santos et al. (2017)	MABC-2	350 Children (188 girls and 162 boys) 350 children (162 boys and 188 girls) aged between 8 and 10. (Associação Brasileira de Empresas de Pesquisa [ABEP], 2008), 1.4% of the students belonged to social class A2, 8% to	Structural validity	Confirmatory factor analysis	Correlations between items and MABC-2 Catching with two hands = 0.31 Throwing beanbag onto mat = 0.33 One-board balance for right foot = 0.73 One-board balance for left foot =0.72 Walking heel to toe forwards = 0.34 Hopping on mats 2 for right foot = 0.37 Hopping on mats 2 for left foot = 0.38 1 factor model: cfd/² = 3.99, GFI = .91, AGFI = .86, CFI= .72, RMSEA =.09 Original 3 factor model: cfd/² = 2.82, GFI = .96, AGFI = 94, CFI= .97, RMSEA =.06	**47%**

		social class B1, 27.1% to social class B2, 35.7 % to social class C1, 17.4% to social class C2, 8.6% to social class C and 1.4% to social class D.			Schulz et al (2011) model: cfd/² = 1.97, GFI = .98, AGFI = .97, CFI= 1, RMSEA =.01	
Ellinoudis and Thomas (2008)	MABC	In total 220 participants - 110 boys and 110 girls (Mean age in months = 126.5, SD = 3.49)	Structural validity	Cronbach's alpha	Age band 3: ranged from .30 to .80. Age band 4: ranged from .41 to .77	**54%**
				Pearson correlation coefficients	Correlation between item score and MABC score Age band 3:	

		Participants were divided into two age groups: First = boys (n=55) and girls (n=55) aged 9 to 10 years (n=110, Mean age in months = 114.74, SD = 3.88) Second = boys (n=55) and girls (n=55) aged 11 to 12 years (n=110, Mean age in months = 138.3, SD = 3.11)			Two-hand catch -.52 Throw bean bag into box -.43 One-board balance-preferred leg -.35 One-board balance-other leg -.39 Hopping in squares-preferred leg -.23 Hopping in squares-other leg -.26 Ball balance .52 Age band 4: One-hand catch-preferred hand -.50 One-hand catch-other hand -.37 Throw at wall target -.46 Two-board balance -.46 Jump and clap -.59 Walking backwards -.30	
				Cohens effect size	Correlation between item score and MABC score Age band 3: Two-hand catch -1.2	

					Throw bean bag into box -1 One-board balance-preferred leg -.75 One-board balance-other leg -.85 Hopping in squares-preferred leg - .5 Hopping in squares-other leg - .55 Ball balance - 1.2 Age band 4: One-hand catch-preferred hand -1.2 One-hand catch-other hand -.8 Throw at wall target -1 Two-board balance -1 Jump and clap -1.5 Walking backwards- .6	
				Principal components factor analysis	Age band 3: Eigen values greater than 1= 5 factors; explaining 77.38% of the variance. Factor 1= 23.2% of variance, included “hopping in squares-preferred leg” and “hopping in squares-non preferred leg”. Labelled as "Dynamic Balance".	

					Factor 2= 17.3% of variance, included “two-hand catch” and “throw bean bag into box”. Labelled "Ball Skills". Factor 3= 16.0% of variance, included “shifting pegs by rows-preferred hand” and “shifting pegs by rows-non preferred hand”. Labelled "Manual Dexterity 1". Factor 4 = 10.5% of variance, included “One-board balance- preferred leg” and “one-board balance- non-preferred leg”. Labelled "Static Balance". Factor 5= 10.19% of variance, included “threading nuts on bolt” and “ball balance”. Labelled "Manual Dexterity 2". <u>Age band 4:</u> Eigen values greater than 1= 4 factors; explaining 72.1% of variance. Factor 1= 27.3% of variance, included “one-hand catch-preferred hand”, “one-hand catch-non preferred	

					hand" and "throw at wall target". Labelled "ball skills". Factor 2= 19.7% of variance, included "turning pegs-preferred hand" and "turning pegs-non preferred hand". Labelled "Motor Speed on Hand Dexterity". Factor 3= 12.8% of variance, included "cutting-out elephant" and "flower trail". Labelled "Motor Accuracy on Hand Dexterity". Factor 4= 12.2% of variance, included "two-board balance" and "walking backwards". Labelled "Balance".	
Estevan et al. (2017)	TGMD-3	178 typically developed children with an age range between 3 and 11 years (Mean age	Internal consistency	ICC	ICC= 0.89 (95% CI, 0.87-0.92)	**57%**
			Inter-rater reliability	ICC	ICC= 0.90 (95% CI, 0.66-0.98)	

		6.94 years (SD = 1.89)) Girls = 47.5% Boys = 52.5%	Intra-rater reliability	ICC	ICC= 0.98 (95% CI, 0.85-1.00)	
			Structural validity	Maximum likelihood model comparing fit with two-factor model	$\chi 2$ (64) = 139.200, $p < 0.01$, RMSEA = 0.073, SRMR = 0.050, NNFI = 0.964, CFI = 0.970,	
Evaggelinou, Tsigilis & Papa (2002)	TGMD	644 children (310 girls; 334 boys) Age ranged from 3 to10 years Participants were divided into two subsamples: The calibration sample: (n = 324) - 150 males (M age = 7.47 years,	Structural validity Hypothesis testing validity	Confirmatory factor analysis	Locomotor: mean factor loading = .50 Gallop: .51 Hop: .63 Jump: .59 Leap: .56 Run: .27 Skip: .47 Slide: .48 Object control: mean factor loading = .57 Bounce: .80 Catch: .61	**61%**

		SD = 1.59) and 174 females (M age = 7.72 years, SD = 1.69) The validation sample: (n = 320) - 160 males (M age = 7.68 years, SD = 1.60) and 160 females (M age = 7.68 years, SD = 1.51)			Kick: .45 Strike: .41 Throw: .61	
Ferreira et al (2020)	BOT-2	931 (477 girls and 454 boys) 603 children enrolled in public schools and 328 children enrolled in private schools	Cross-Cultural Validity	Percentile curves	Brazilian children showed better results in bilateral coordination, balance, upper-limb coordination, and running speed and agility subtests (difference range 0.03 - 6.90 points). Upper limb coordination and balance subtests curves were similar.	**46%**

		All aged between 6-10 years old				
Field et al (2020)	TGMD-2 and TGMD-3	Final sample: n = 270 (54% female; mean age in grade 3 = 8 years 6 months) 11 children were reported as having a disability or chronic health condition (by their parents)	Reliability / Measurement Error (Inter-Rater Reliability)	Percent Agreement	Inter-rater reliability between the primary investigator and a second trained research assistant: TGMD-2 (.88) TGMD-3 (.87)	**30%**
			Reliability / Measurement Error (Intra-Rater Reliability)	Percent Agreement	Intra-rater reliability: TGMD-2 (.98) TGMD-3 (.95)	
			Criterion Validity (Concurrent Validity)	Paired samples t-tests	Significant difference ($p < .05$) between the tests (TGMD-2 and TGMD-3) in grade 3 Significant difference ($p < .05$) between tests in grade 4	

					Significant difference ($p < .05$) between tests in grade 5	
Fransen et al., (2014)	BOT-2 Short Form; KTK	2485 children (1300 boys and 1185 girls) aged between 6 and 12 years	Concurrent Validity Hypothesis testing validity	Pearson correlations	Total BOT-2 Short Form score & KTK motor quotient ($r = 0.61$, $p < 0.001$) BOT- 2 Short Form gross motor composite score & KTK motor quotient ($r = 0.44$, $p < 0.001$) BOT-2 Short Form fine motor composite score and KTK Motor Quotient ($r = 0.25$, $p < 0.001$)	**47%**

Furtado and Gallagher (2012)	FG-COMPASS	131 children from 6-11 years Volunteers from private schools in Western Pennsylvania	Inter-rater reliability	Overall agreement (Ao)	Locomotor: Hopping: Ao= 87% Horizontal jumping Ao= 74% Leaping Ao=66% Skipping Ao= 82% Side sliding Ao= 66% Manipulative: Batting Ao=82% Catching Ao: 77% Kicking Ao= 61% Overhand throwing Ao=76% Side-arm striking Ao=84% Stationary dribbling Ao= 76%	**43%**
				Weighted kappa (Kw)	Locomotor: Hopping: KW= .85 Horizontal jumping: KW= .70 Leaping: KW= .61 Skipping: KW= .77 Side sliding: KW= .61 Manipulative:	

					Batting: KW= .79 Catching: KW= .72 Kicking: KW= .51 Overhand throwing: KW= .74 Side-arm striking: KW= .79 Stationary dribbling: KW= .72	
				Specific agreement (Ps)	Locomotor: Hopping: P (I) = .93, P(E) = .79, P(A) = .88 Horizontal jumping: P(I) = .65, P(E) = .63, P(A)= .97 Leaping: P(I) = .70, P(E)= .43, P(A)=.80 Skipping: P(I)= .93, P(E)= .77, P(A)= .74 Side sliding: P(I)= .77, P(E) = .40, P(A)= .73 Manipulative: Batting: P(I)= .82, P(E)= .75, P(A)=.90 Catching: P(I)= .71, P(E)= .72, P(A)= .88 Kicking: P(I)= 28, P(E) = .56, P(A)= .91 Overhand throwing: P(I)= .74, P(E)= .50, P(A)= .97 Side-arm striking: P(I)= .86, P(E)= .83, P(A)=.83 Stationary dribbling: P(I)= .78, P(E)= .65, P(A)= .84	

Garn and Webster (2017)	TGMD-2	1,120 children between the ages of 3 and 10 years (M age = 7.04, SD = 2.23 years) 49.7% =male 50.3% =female Racial/ethnic backgrounds: 60.89% White/ Caucasian, 17.59% Black/ African-American, 14.29% Hispanic, 3.30% Asian,	Structural validity	CFA	1 factor model: $\chi2$ = 416.03 (54), p=.001, CFI=.95, RMSEA=.06 2 factor model: $\chi2$ = 250.24 (53), p=.001, CFI=.97, RMSEA=.05, r=.89	**79%**
			Hypothesis Testing Validity	Exploratory SEM	2 Factor: $\chi2$ = 164.63 (43), p=.001, CFI=.98, RMSEA=.04, r=.81	

		2.77% Mixed racial/Other, and 1.16% Native American. Approximately 7% of the participants had a disability				
Hoeber et al. (2018)	Athletic Skills Tract (AST) and KTK	717 (344 girls and 373 boys) children in study 1 Mean age (SD) = 9 (2) years 213 (104 girls and 109 boys) other children in study 2	Test- retest reliability for AST	Intraclass correlation coefficient	AST-1: 0.881 (95% CI: 0.780–0.934) AST-2: 0.802 (95% CI: 0.717–0.858) AST-3: 0.800 (95% CI: 0.669– 0.871)	**55%**
				Limits of agreement (LoA)	AST-1: (mean = 0.79, [LoA] −3.02 and 4.60) AST-2: (mean = 1.47, [LoA] −6.12 and 9.06)	

		Mean age (SD) = 9 (2) years			AST-3: (mean = 1.68, [LoA] −5.14 and 8.50)	
			Internal consistency of AST	Cronbach's α	AST-1: α = 0.764 AST-2: α = 0.700 AST-3: α = 0.763	
			Criterion Validity (Concurrent) with KTK	Pearson's correlation coefficients quotients of the KTK)	AST-1: r = −0.747, p = 0.01 AST-2: r = −0.646, p = 0.01 AST-3: r = −0.602, p = 0.01	

Hoeboer et al. (2016)	Athletic Skills Track 1 and 2 (AST-1&2) KTK	463 children (211 girls, 252 boys) aged between 6 and 12 years Mean age = 9 ± 2 years	Criterion Validity (Concurrent)	Pearson correlation	AST-1 and KTK (r = –0.474, P < 0.01) AST-2 and KTK (r = –0.502, P < 0.01) Gender split AST-1 and KTK: girls: r = –0.501, P < 0.01; boys: r = –0.533, P < 0.01 Gender split AST-2 and KTK girls: r = –0.448, P < 0.01; boys: r = –0.566, P < 0.01	**45%**
			Test-retest reliability	Intraclass correlation	Between the first and second AST-1 trial = 0.875 (95% CI [0.852–0.895]) Between the first and second AST-2 trial = 0.891 (95% CI [0.870–0.908])	

				Paired sample t test	AST-1 trials 1 and 2 t = 6.026, P < 0.05 AST-2 trials 1 and 2 t = 8.226, P < 0.05	
Holm, Tveter, Aulie & Stuge (2013)	MABC-2	45 healthy children s (7–9 years of age) Females = 23 Males = 22 Mean age (SD) = 8.7 (0.7) yrs 43 (95.5%) children had no movement problems and 2 (4.5%)	Intra-tester reliability	Intraclass correlation (with 95% Cl and SEM)	<u>Aiming and catching:</u> Catching with two hands, no. of catches = 0.48 [0.15,0.72], SEM = 1.5 Throwing bean bag on to mat = 0.59 [0.29,0.79], SEM = 1.0 <u>Balance:</u> One-board balance, right leg = 0.56 [0.26,0.77], SEM = 4.0 One-board balance, left leg = 0.70 [0.45,0.85], SEM = 5.3	**43%**

		children were classified as having impaired motor problems 30 children were included in the inter-tester part of the study, 29 children in the intra-tester part, 14 took part in both studies			Walking heel-to-toe forwards = 0.75 [0.53,0.87], SEM = 0.9 Hopping on mats, right leg = NA Hopping on mats, left leg = 0.24 [-0.15,0.56], SEM = 0.6 <u>Domains (component score):</u> Aiming and catching = 0.49 [0.17,0.72], SEM = 2.4 Balance = 0.49 [0.15,0.72], SEM = 2.7 <u>Total score:</u> Total test score = 0.68 [0.28,0.85], SEM = 4.9 Total standard score = 0.64 [0.23,0.84], SEM = 1.4	
			Inter-rater reliability	Intraclass correlation	<u>Aiming and catching:</u> Catching with two hands = 0.66 [0.40,0.82], SEM = 1.3	

				(with 95% Cl and SEM)	Throwing bean bag on to mat = 0.62 [0.33,0.80], SEM = 1.1 Balance: One-board balance, right leg = 0.39 [0.05,0.65], SEM = 5.8 One-board balance, left leg = 0.50 [0.19,0.73], SEM = 7.3 Walking heel-to-toe forwards = 0.42 [0.06,0.67], SEM = 1.6 Hopping on mats, right leg = NA Hopping on mats, left leg = NA Domains (component score): Manual dexterity = 0.63 [0.35,0.80], 3.2 Aiming and catching = 0.77 [0.56,0.89], SEM = 2.0 Balance = 0.29 [-0.07,0.58], SEM = 4.5 Total score: Total test score = 0.62 [0.35,0.80], SEM = 6.8 Total standard score = 0.63 [0.36,0.80], SEM = 1.6	

Houwen et al (2010)	TGMD-2 and MABC	75 children with VI (aged between 6 and 12 years, 29 girls; 46 boys) Of these 75 children, 8 children attended special-needs schools and 67 children attended mainstream primary schools. 71 children were Caucasian while 4 were	Internal consistency	Cronbach's Alpha	Locomotor= 0.71 Item deleted= 0.61-0.68 Item-total correlations= 0.36-0.54 Inter-item correlations= 0.11 to 0.45 Object control= 0.72 Item deleted= 0.63-0.71 Item-total correlations= 0.30-0.54 Inter-item correlations= 0.14 to 0.51	64%
			Inter-rater reliability TGMD	ICCs (95% CIs)	Locomotor= 0.82 (0.70-0.90) Object control=0.93 (0.88-0.96)	

		of Asian descent.			Total test=0.89 (0.81-0.93)	
			Intra-rater reliability TGMD	ICC	Locomotor= 0.85 (0.69-0.93) Object control = 0.93 (0.84-0.97) Total test= 0.95 (0.88-0.98)	
			Test-retest reliability TGMD	ICC	Locomotor= 0.86 (0.70-0.94) Object control= 0.87 (0.72-0.94) Total test= 0.92 (0.82-0.91)	
			Structural validity	Factor analysis	Fit Indices: Chi-square (Df = 53) = 79.55, *p* = 0.01, Df ratio = 1.50, RMSEA = 0.07, GFI = 0.85. <u>Locomotor factor loadings</u> Run=.50 (p < .05) Gallop=.44 (p < .05.)	

					Hop=.49 (p < .05.) Leap=.61 (p < .05.) Jump=.51 (p < .05.) Slide=.76 (p < .05.) <u>Object control skills factor loadings</u> Strike= .32 (p < .05.) Dribble= .73 (p < .05.) Catch= .57 (p < .05.) Kick= .62 (p < .05.) Throw= .68 (p < .05.) Roll= .61(p < .05.) Correlation between LOC and OC= 0.81	
			Criterion Validity (Concurrent) TGMD and MABC	Spearman Rho	TGMD-2 object control subtest and the Movement ABC ball skills subtest Age band 2= rs = 0.57, *p* = 0.001 Age band 3= rs = 0.45, *p* = 0.040	
Hua, Gu, Meng & Wu (2013)	MABC-2 and PDMS-2	1823 children in total	Internal consistency MABC	Cronbach's alpha	Catching beanbag = .428	**67%**

		(Females = 908 and Males = 915) Aged 36–72 months old (mean = 61.284 months, SD = 10.212 months)			Throwing beanbag onto mat = .427 One leg balance = .445 Walking heels raised = .517 Jumping on mats = .489	
				Pearson correlation coefficients (Item-total correlation)	Catching beanbag = .587 Throwing beanbag onto mat = .603 One leg balance = .525 Walking heels raised = .228 Jumping on mats = .405	
			Inter-rater reliability	Intraclass correlation (with 95% Cl)	Catching beanbag (number of correct catches out of 10) = .993 (.992, .994)	

					Throwing beanbag onto mat (Number of correct catches out of 10) = .979 (.977, .981) One-leg balance with preferred leg (number of seconds balanced) = .997 (.997, .998) One-leg balance with non-preferred leg (number of seconds balanced) = .998 (.997, .998) Walking heels raised (number of correct steps) = .895 (.886, .904) Jumping on mats (number of correct jumps/hops out of 5) = .993 (.993, .994)	
			Test-retest reliability	Intraclass correlation (with 95% Cl)	Catching beanbag (number of correct catches out of 10) = .934 (.912, .950) Throwing beanbag onto mat (Number of correct catches out of 10) = .905 (.874, .928)	

					One-leg balance with preferred leg (number of seconds balanced) = .970 (.959, .977) One-leg balance with non-preferred leg (number of seconds balanced) = .985 (.979, .988) Walking heels raised (number of correct steps) = .832 (.781, .871) Jumping on mats (number of correct jumps/hops out of 5) = .936 (.916, .952)	
			Content validity	Item-level content validity index	Catching beanbag (number of correct catches out of 10) = 1.0 Throwing beanbag onto mat (Number of correct catches out of 10) = 1.0 One-leg balance (number of seconds balanced) = 1.0 Walking heels raised (number of correct steps) = .96	

					Jumping on mats (number of correct jumps/hops out of 5) = .96 The average = .985	
			Structural validity	Confirmatory Factor Analysis	Original 8 item model (Henderson, 2007) x2 = 80.149, df = 17, x2/df = 4.715, p < 0.001, GFI = 0.976, AGFI = 0.950, IFI = 0.850, CFA = 0.846, RMSEA = 0.067 7 item model (heels raised removed) x2 = 35.828, df = 11, x2/df = 3.257, p < 0.001, GFI = 0.988, AGFI = 0.969, IFI = 0.935, CFA = 0.933, RMSEA = 0.043 6 item model (drawing trail removed) x2 = 11.749, df = 6, x2/df = 1.958, p = 0.068, GFI = 0.995, AGFI = 0.984, IFI = 0.984, CFA = 0.984, RMSEA = 0.034).	

			Criterion Validity (Concurrent)	Spearman's correlation	MABC-2 gross motor (aiming and catching): PMDS-2 gross motor = 0.743 PMDS-2 total = 0.628 MABC-2 balance: PMDS-2 gross motor = 0.066 PMDS-2 total = 0.165 MABC-2 total: PMDS-2 gross motor = 0.457 PMDS-2 total = 0.631	
Iatridou & Dionyssiotis (2013)	BOT (balance subtest)	20 children with Cerebral Palsy from Special Education Schools in Greece 6-14 years	Test-retest reliability	Intraclass correlation	Between the 1st-2nd = 0.978 (p<.001) Between the 1st-3rd = 0.993 (p<.001) Between the 2nd-3rd = 0.989 (p<.001) Between the three measurements (1st, 2nd and 3rd) 3=0.987 (p<.001)	**57%**

		Females = 8 Males = 12 Diagnosis of hemiplegia, or diplegia with the capacity of self-support walking 8 children has diplegia				
Issartel, McGrane, Fletcher, O'Brien, Powell, Belton et al. (2017)	TGMD-2	In total 844 participants (males = 456, females = 388) Aged 12.03	Test-retest reliability	Pearson product moment correlation	Locomotor = 0.78 Object related = 0.76 Gross motor skills = 0.91	**47%**

		years ± 0.49 (median = 12.89)				
			Structural Validity	Confirmatory Factor Analysis	Full model two correlated factors χ^2= 175.26 (53), p<.001, CFI=.59, RMSEA = .05 Full one factor model: χ^2= 187.24 (54), p<.001, CFI=.7, RMSEA = .05 Reduced model one factor χ^2= 111.29 (35), p<.001, CFI=.68, RMSEA = .05 Reduced model two correlated factors χ^2= 87.11 (34), p<.001, CFI=.77, RMSEA = .04	

Jaikaew & Satiansukpong (2019)	MABC-2, Thai version	30 children were recruited for the inter-rater reliability study 5 children were recruited for testing MABC-2 All aged 7 years and 0 months to 10 years and 11 months with	Reliability / Measurement Error (Inter-rater reliability)	Intraclass Correlation Coefficient (ICC with 95% CI)	Aiming and Catching: Catching with Two Hands 0.99 (0.98-0.99) Throwing a Beanbag onto a Mat 0.94 (0.88-0.97) Balance: One-Balance Board (other leg) 1.00 (0.99-1.00) Walking Heel-to-Toe Forwards 0.99 (0.99-0.99) Hopping on Mats (best leg) NA Hopping on Mats (other leg) 0.96 (0.92-0.98)	**29%**

		no "physical limitations"	Content validity	Item objective congruence (IOC) index	Manual Dexterity with: Language clarity (.73) Language pertinence (.83) Aiming and Catching with: Language clarity (.88) Language pertinence (.95) Balance with: Language clarity (.89) Language pertinence (.94)	
Jirovec, Musalek & Mess (2019)	BOT-2 (CF) and BOT-2 (SF)	153 children aged 8 to 11 (M = 9.53 ± 0.85 years), (boys n = 84, girls n = 69)	Criterion Validity (Concurrent Validity) short form and complete form	Pearson's product moment correlations	Manual coordination: 0.24* Body coordination: 0.42** Strength and agility: 0.08	**54%**

				Receiver Operating Characteristic (ROC) analysis of BOT-2 SF	BOT-2 SF: High sensitivity (84%) Poor specificity (42.9%) Accuracy (76.5%) Poor value of Empirical Area Under Curve Analysis (AUC) = 0.484 CI95% (0.31–0.62) ROC analyses conducted for boys and girls separately for BOT-2 SF: High sensitivity (boys = 82.6%, girls = 85.7%) Low specificity (boys = 53%, girls = 30.7%)	
Kim, Kim, Valentini & Clark (2014)	TGMD-2	141 children aged from 3 to 10 years old Mean age (SD) = 6.8 (1.9) years	Internal consistency	Cronbach's alpha coefficient	Between the two subtests = .87 Locomotor subset = .82 Object control subset = .73	**57%**
			Inter-rater reliability	Pearson's correlation	Summed score: Testers A x B = .94** Testers A x C = .87**	

					Tetsers B x C = .86* Score from locomotor subtest: Testers A x B = .89** Testers A x C = .81** Testers B x C = .83** Score from object control subtest: Testers A x B = .92** Testers A x C = .87** Testers B x C = .86** Testers A x B x C = .92**	
				Intraclass correlation	Summed score: Testers A x B = .97*** Testers A x C = .93*** Testers B x C = .92*** Testers A x B x C = .96*** Score from locomotor subtest:	

					Testers A x B = .94*** Testers A x C = .90*** Testers B x C = .91*** Testers A x B x C = .94*** Score from object control subtest: Testers A x B = .85** Testers A x C = .80* Testers B x C = .77*	
			Test-retest reliability	Pearson's correlation	Between the raw scores of the locomotor subset = .90, $p < .0001$ Between the raw scores of the object control subtest = .85, $p < .0001$	
			Structural validity	Confirmatory factor analysis	<u>2 factor model:</u> $x2(54) = 86.59$, $p = .003$ CFI =0.94, TLI =0.93, NFI =0.87, GFI = 0.91, and IFI = 0.95	

Kim, Park & Kang. (2012)	TGMD-2	22 children in total with intellectual disabilities (aged between 8.6 to 11.2 yrs, Mean age 9.9 (± 1.3) years) 16 = boys 6 = girls	Inter-rater reliability	ICC	Locomotor skills: Kicking= 0.85 (0.65, 0.50) Striking a stationary ball= 0.91 (0.78, 0.75) Underhand roll= 0.94 (0.83, 0.79) Overhand throw= 0.93 (.81, 0.78) Stationary bouncing= 0.89 (0.72, 0.70) Catch= 0.88 (0.72, 0.53) Subtotal score= 0.90 (.75, 0.71) Object control skills: Hop= 0.93 (0.82, 0.79) Horizontal jump= 0.92 (0.80, 0.70) Slide= 0.94 (.84, 0.81) Run=0.89 (0.73, 0.72) Gallop= 0.95 (0.86, 0.85) Leap= 0.91 (0.78, 0.68) Subtotal score= 0.93 (0.80, 0.78) Total score= 0.91 (0.78, 0.75)	**54%**

Kita, Suzuki, Hirata, Sakihara, Inagaki & Nakai (2016)	MABC-2	132 children in total (Females = 48 and Males = 84) Aged from 7.0 to 10.8 years (mean = 8.8 and standard deviation (SD) = 1.2) 58, 29, and 45 children were recruited from urban, middle-urban, and rural areas respectively	Internal consistency	Item-total correlation	Catching with Two Hands = 0.536 Throwing Beanbag onto Mat = 0.504 One-Board Balance = 0.573 Walking Heel-to-Toe Forwards = 0.534 Hopping on Mats = 0.480	**81%**
				Cronbach's alpha	Catching with Two Hands = 0.557 Throwing Beanbag onto Mat = 0.581 One-Board Balance = 0.531 Walking Heel-to-Toe Forwards = 0.546 Hopping on Mats = 0.537	

			Structural validity	Confirmatory factor analysis	χ^2 (17) = 12.685, p=.757; v2/df=0.746; GFI=.977; AGFI = .951; CFI = .999; RMSEA = .000	
Lander, Morgan, Salmon, Logan & Barnett (2017)	CAMSA & Victorian FMS	34 children in total (all female) Mean age (± SD) = 12.6 years (± 0.04) Demographics:	Test-retest reliability	Intraclass correlation (with 95% Cl)	CAMSA: total score = 0.91 (Cl = 0.83,0.95) CAMSA: time score = 0.80 (Cl = 0.63,0.89) CAMSA: skill score = 0.85 (Cl =0.73,0.92) Victorian FMS = 0.79 (Cl = 0.62,0.89)	**49%**
				Bland–Altman	CAMSA - mean −1.29, [LoA] −5.62 and 3.04	

		17 = Australian 9 = Asian 8 = European			Victorian FMS Assessment - mean −0.38, [LoA] −6.82 and 6.06	
				Bivariate correlation	CAMSA - r = 0.02, p = 0.89 Victorian FMS Assessment instrument - r = −0.12, p = 0.49	
			Criterion Validity (Concurrent)	Spearman's Rho	Between the finishing position of students in the CAMSA using their total CAMSA score and Victorian FMS Assessment in Test 1: rs = 0.68, p = <0.05 When isolating the skill score of the CAMSA, with the total skill score of the Victorian FMS Assessment: rs = 0.60, p = <0.05	
Lane & Brown (2015)	BOT-2 and MABC-2	50 typically developing children aged 7–16 years. The sample was divided	Criterion validity (concurrent)	Spearman's rho	<u>MABC Age Band 2 – Balance:</u> BOT bilateral coordination = -.1 BOT Balance = .11 BOT Running speed & agility = .14 BOT strength = .37	**77%**

		into two age bands: AB2 (7–10 years): 25 children (14 females and 11 males). Mean age of 8 years 11 months (SD = 1 year, 1 month) AB3 (11–16 years): 25 children (11 females and 14 males). Mean age of 13 years 4 months (SD = 1 year 8 months).			BOT body coordination =.13 BOT strength and agility = .32 <u>MABC Age Band 2 – Aiming and catching</u> BOT bilateral coordination = -.08 BOT Balance = .35 BOT Running speed & agility = .14 BOT strength = -.1 BOT body coordination = .17 BOT strength and agility = .17 <u>MABC Age Band 3– Balance:</u> BOT bilateral coordination = .15 BOT Balance = .31 BOT Running speed & agility = .45 BOT strength = .51 BOT body coordination =.29 BOT strength and agility = .45 <u>MABC Age Band 3 – Aiming and catching</u>	

		.			BOT bilateral coordination = .26 BOT Balance = .01 BOT Running speed & agility = .25 BOT strength = .44 BOT body coordination = .03 BOT strength and agility = .44	
Laukkanen et al (2020)	KTK	Pooled data from four independent studies in: Finland (1) Mean age 6.64 ± 0.36 years, range 1.8 years, n = 278 Finland (2):	Internal consistency	Cronbach's alphas	Cronbach's alphas of the KTK test items: Finland (combined) 0.828 Belgium 0.804 Portugal 0.777	**51%**

		Mean age 8.60 ± 0.85 years, range 3.3 years, n = 412 Belgium: Mean age 8.25 ± 1.09, range 4 years, n = 1896 <u>Portugal:</u> Mean age 8.31 ± 1.02, range 3.9 years, n = 758				
				Item-total correlations	The corrected item-total correlations for the norm-based values of test items: Finland Walking backwards .571 Hopping for height .710 Jumping sideways .695 Moving sideways .655 The corrected item-total correlations for the norm-based values of test items: Belgium Walking backwards .549 Hopping for height .656 Jumping sideways .687 Moving sideways .588	

					The corrected item-total correlations for the norm-based values of test items: Portugal Walking backwards .648 Hopping for height .578 Jumping sideways .680 Moving sideways .616	
Liao, Mao & Hwang (2001)	BOT	20 TD children mean = 10.6 years, SD= 2.3 years 6 males, 14 females	Test-retest reliability	% agreement	One-leg standing on floor – 100 On balance beam – 80 on balance beam, eyes closed – 40 Walking forward on walking line – 100 On balance beam - 70 heel-to-toe on walking line - 50	**35%**

					heel-to-toe on balance beam – 50 Stepping over stick on balance beam - 50	
Logan, Barnett, Goodway & Stodden (2017)	TGMD-2 and GSGA	170 children in total aged between 4 and 11 years old. (Females = 86 Males = 84) Participants were Hispanic (n = 94), Caucasian (n = 70), African American (n = 5) and Native American (n = 1).	Criterion Validity (Concurrent)	Spearman's rho (* and ** indicate significance at the .05 and .01 levels, respectively)	<u>Jump:</u> TGMD-2: 4-5 years old = .46** 7-8 years old = .26* 10-11 years old = .47** GSGA: 4-5 years old = .53** 7-8 years old = 0.17 10-11 years old = .41** <u>Hop:</u> TGMD-2: 4-5 years old = .65** 7-8 years old = .41** 10-11 years old = 0.25	**55%**

		Participants were split into the following age groups: 4–5 year olds: (n = 55, boys = 23, girls = 32). Mean age (SD) = 5 (0.54) years 7–8 year olds: (n = 61, boys = 33, girls = 28). Mean age (SD) = 8.1 (0.62) years 10–11 year olds: (n = 54, boys = 28, girls = 26). Mean age			GSGA: 4-5 years old = .88* 7-8 years old = .48** 10-11 years old = .47** <u>Throw:</u> TGMD-2: 4-5 years old = .30* 7-8 years old = .47** 10-11 years old = .62** GSGA: 4-5 years old = .29* 7-8 years old = .45** 10-11 years old = .71**	
				Cochran's Q tests	Assessments differed in classifying: standing long jump Q(2) = 14.1, P < .01	

		(SD) = 10.7 (0.42) years			Hopping Q(2) = 67.2, P < .001 Throwing Q(2) = 100.2, P < .001)	
Logan, Robinson, Rudisill, Wadsworth& Morera (2014)	TGMD-2 and GSGA	65 children in total (Females = 33 and Males = 32) Kindergarten: (n = 20, 10 boys, 10 girls, mean age = 5.7 + 0.38 years) First grade: (n = 22, 13 boys, 9 girls, mean age = 6.7 + 0.34 years) Second grade: (n = 23, 9 males, 14 females, mean	Criterion Validity (Concurrent)	Spearman correlations	4-5 yrs Jump = .5 Hop = .68 Throw = .59 7-8 yrs Jump = .48 Hop = .51 Throw = .66 10-11 yrs Jump = .17 Hop = .47 Throw = .7	**55%**

		age = 7.8 + 0.46 years) Demographics: 72.3% = African-American, 20% = Hispanic, 7.7% = Caucasian				
Longmuir et al (2017)	CAMSA	1165 children Females = 598 males = 567 8-12 years	Test-retest reliability	ICC	Completion time across short (n = 59; ICC = 0.84; 95%CI: 0.74 to 0.91) and long (n = 16; ICC = 0.82; 95%CI: 0.53 to 0.93) test intervals	**77%**
			Inter-rater reliability	ICC	<u>Skill score:</u> All trials = 0.69 (Cl = 0.61, 0.76) Trial 1 = 0.70 (Cl = 0.61, 0.79) Trial 2 = 0.66 (Cl = 0.55, 0.77)	

					<u>Completion time:</u> All trials = 0.997 (Cl = 0.995, 0.998) Trial 1 = 0.997 (Cl = 0.994, 0.998) Trial 2 = 0.993 (Cl = 0.990, 0.995)	
			Intra-rater reliability	ICC	<u>Skill Score:</u> All examiners = 0.52 (Cl = 0.43, 0.60) Examiner 1 = 0.45 (Cl = 0.20, 0.64) Examiner 2 = 0.55 (Cl = 0.33, 0.72) Examiner 3 = 0.43 (Cl = 0.19, 0.63) Examiner 4 = 0.52 (Cl = 0.28, 0.69)	

					Examiner 5 = 0.49 (Cl = 0.26, 0.67) Examiner 6 = 0.57 (Cl = 0.35, 0.73) Examiner 7 = 0.53 (Cl = 0.30, 0.70) <u>Completion time</u> All examiners = 0.996 (Cl = 0.995, 0.997) Examiner 1 = 0.999 (Cl = 0.999, 1.000) Examiner 2 = 0.998 (Cl = 0.998, 0.999) Examiner 3 = 0.991 (Cl = 0.986, 0.994) Examiner 4 = 0.996 (Cl = 0.994, 0.997)	
Lopes, Saraiva, &	TGMD-2	330 children in total (Females =	Test–retest Reliability	Bland-Altman analysis	95% limits of agreement ranged from 0.80 to 1.13, agreement ratio = 0.96 (0.09).	**62%**

Rodrigues (2018)		164 and Males = 166) Aged between 5–10 years of age (Mean age with SD = 7.9 ± 1.3)			Locomotor - 95% limits of agreement ranged between 0.85 and 1.17, agreement ratio= 1 (0.08). Object Control- 95% limits of agreement ranged between 0.63 and 1.16, agreement ratio = 0.80 (0.13).	
			Inter-rater reliability	Kappa	Ranged .7 - 1	
			Internal consistency	Cronbach's alpha	Whole test = .69 Locomotor = .46 Object control = .64	
			Structural validity	CFA 2 factor model	CFI = .956, NFI = .868, NNFI = .937, SRMR = .048, RMSEA = .036 (90% CI: .010–.054) All loading coefficients were significant ($p < .05$), with factor loadings ranging from .31 to .76.	

			Hypothesis testing validity		High correlation (r = .77; $p < .05$) between the two factors	
Lucas et al. (2013)	BOT-2	30 participants Females = 12 Males = 18 Aboriginal and Torres Straight Island Background Mothers in the sample drank alcohol during pregnancy	Inter-rater reliability	Intraclass correlation	Bilateral co-ordination: Jumping in place (same sides synchronized) = .34 Tapping feet and fingers (same sides synchronized) = N/A Balance: Walking forward on a line = N/A Standing on one leg on a balance beam (eyes open) = .54 Running speed and agility: One legged stationary hop = .49 Upper-limb co-ordination: Dropping and catching a ball (both hands) = 1.00 Dribbling a ball (alternating hands) = .85	**83%**

					<u>BOT-2 score sheet outcomes:</u> Total point score (Raw) = .92 Standard score (standardized for gender and age) = .89 Percentile rank (%) = .88	
			Test-retest reliability	Intraclass correlation	<u>Bilateral co-ordination:</u> Jumping in place (same sides synchronized) = -0.066 Tapping feet and fingers (same sides synchronized) = -0.032 <u>Balance:</u> Walking forward on a line = N/A Standing on one leg on a balance beam (eyes open) = .17 <u>Running speed and agility:</u> One legged stationary hop = .25 <u>Upper-limb co-ordination:</u> Dropping and catching a ball (both hands) = -0.041	

					Dribbling a ball (alternating hands) = .023 BOT-2 score sheet outcomes: Total point score (Raw) = .62 Standard score (standardized for gender and age) = .73 Percentile rank (%) = .71	
Maeng et al. (2017)	TGMD-3	10 typically developing children (6 boys and 4 girls) Age ranged from 3 years, 7 months to 10 years, 9 months old (Mean age = 6.57, SD = 2.51 years)	Inter-rater reliability	ICCs (95% CIs)	Locomotor skills: Run= 0.66 (0.39 to 0.88) Gallop= 0.66 (0.39 to 0.88) Hop= 0.92 (0.82 to 0.98) Skip= 0.90 (0.78 to 0.97) Horizontal jump= 0.81 (0.61 to 0.94) Slide= 0.67 (0.41 to 0.88) Subscale score= 0.92 (0.82 to 0.98) Ball skills: Two-handed strike= 0.81 (0.61 to 0.94) One-handed strike= 0.86 (0.70 to 0.96)	**61%**

		Demographics: 70% = White 30% = African American			One-handed dribble= 0.92 (0.81 to 0.98) Two-handed catch= 0.67 (0.41 to 0.88) Kick= 0.51 (0.22 to 0.80) Overhand throw= 0.78 (0.57 to 0.93) Underhand throw= 0.79 (0.59 to 0.93) Subscale score= 0.93 (0.84 to 0.98) Total score= 0.96 (0.91 to 0.99)	
			Intra-rater reliability	ICC (95% Cis)	<u>Locomotor skills:</u> Run= 0.91 (0.84 to 0.95) Gallop= 0.86 (0.76 to 0.92) Hop= 0.93 (0.88 to 0.96) Skip= 0.95 (0.91 to 0.97) Horizontal jump= 0.90 (0.83 to 0.94) Slide= 0.84 (0.73 to 0.90) Subscale score= 0.98 (0.96 to 0.99) <u>Ball skills:</u> Two-handed strike= 0.86 (0.77 to 0.92) One-handed strike= 0.92 (0.87 to 0.96)	

					One-handed dribble= 0.95 (0.92 to 0.97) Two-handed catch= 0.87 (0.79 to 0.93) Kick= 0.77 (0.63 to 0.87) Overhand throw= 0.93 (0.87 to 0.96) Underhand throw= 0.87 (0.78 to 0.93) Subscale score= 0.96 (0.94 to 0.98) Total score= 0.98 (0.96 to 0.99)	
Magistro et al. (2020)	TGMD-3	5210 children age range of 3-11; mean age years = 8.38, SD = 1.97; % females = 48. .	Test-retest reliability	Intraclass Correlations	<u>6 years old group (n = 50):</u> Locomotor = (ICC = .993; CI [.987, .996]), Ball skills scales = (ICC = .992; CI [.986, .995]), TGMD-3 total= ICC = .991; CI [.983, .995]), <u>7 years old group (n = 50):</u> Locomotor = ICC = .983; CI [.971, .990]), Ball skills scales = (ICC = .989; CI [.981, .984]), TGMD-3 total= ICC = .979; CI [.964, .988]), <u>8 years old group (n = 50):</u> Locomotor = ICC = .985; CI [.974, .992]), Ball skills scales = (ICC = .993; CI [.987, .996]), TGMD-3 total= ICC = .981; CI [.967, .989]), <u>9 years old group (n = 50):</u> Locomotor = ICC = .991; CI [.985, .995]),	**64%**

					Ball skills scales = (ICC = .995; CI [.991, .997]), TGMD-3 total= ICC = .989; CI [.980, .993]), 10 years old group (n = 50): Locomotor = ICC = .990; CI [.983, .994]), Ball skills scales = (ICC = .996; CI [.993, .998]), TGMD-3 total= ICC = .993; CI [.987, .996]), 11 years old group (n = 50): Locomotor = ICC = .982; CI [.968, .990]), Ball skills scales = (ICC = .994; CI [.989, .996]), TGMD-3 total= ICC = .984; CI [.972, .991])	
			Inter-rater reliability	Intraclass correlation coefficients	TGMD-3 total scores = 0.973; 95% CI: Lower Bound = 0.969 and Upper Bound = 0.977).	
			Structural validity	Exploratory and confirmatory factor analysis	CFA with ML estimation method $\chi 2$= 916.284, df = 64, $p < 0.001$, RMSEA = 0.050 (90% Confidence Intervals: 0.048, 0.053), CFI = 0.955. Factor loadings were all significant at $p < 0.001$ and ranged between 0.583–0.671. Locomotor Skills Run: EFAβ= .323 / CFAβ= .671 Gallop: EFAβ= .363 / CFA β= .615 Hop: EFA β= .405 / CFA β= .675	

					Skip: EFA β= .426 / CFA β= .584 Horizontal jump: EFA β= .426 / CFAβ= .622 Slide: EFA β= .454 / CFA β= .585 <u>Ball skills</u> Forehand strike of self-bounced ball: EFA β= .387 / CFA β= .565 One-hand stationary dribble: EFA β= .433 / CFA β= .656 Two-hand catch: EFAβ= .374 / CFA β= .604 Kick a stationary ball: EFA β= .244 / CFA β= .629 Overhand throw: EFA β= .421 / CFA β= .603 Underhand throw: EFA β= .353 / CFA β= .589 Two-hand strike of a stationary ball: EFA β= .376 / CFA β= .597	
Mancini, Rudaizky, Howlett, Elizabeth-Price & Chen (2019)	BOT-2	86 children with ADHD. 78 males and 6 females aged 6-14 years (M = 9 years, 11 months; SD = 1 year, 9 months).	Criterion Validity (Concurrent) (Long- and short-form BOT-2)	Pearson's bivariate correlation	<u>Correlation with domain score</u> Jumping in place-same sides synchronised = .561* Tapping feet and fingers-same sides synchronised = .587* Walking forward on a line = .173 Standing on one leg on a balance beam - eyes open = .122 One-legged stationary hop = .676* Dropping and catching a ball - both hands = .333*	**53%**

					Dribbling a ball - alternating hands = .323* *p<.001.	
Moreira, Lopes, Miranda-Junior, Valentini, Lage & Albuquerque (2019)	KTK	565 volunteers from 5 to 10 years of age (age mean = 7.93 ±1.51. 49.9% were boys (n= 282) and 50.1% were girls (n= 283), all whom are enrolled in Brazilian public and private schools (from 1st to 5th grade of elementary school).	Structural Validity	Confirmatory factorial analysis (CFA)	$\chi2$ = 5.086, *p* = 0.079, CFI = 0.995, TLI = 0.986, RMSEA = 0.052, SRMR = 0.015). CFA for male group ($\chi2$ = 2.733, *p* = 0.255, CFI = 0.998, TLI = 0.993, RMSEA =0.036, SRMR = 0.016) CFA for female group ($\chi2$ = 3.255, *p*= 0.196, CFI = 0.997, TLI = 0.990, RMSEA = 0.047, SRMR = 0.016). CFA for 5 to 7 years old group ($\chi2$ = 0.340, *p*= 0.844, CFI = 1.000, TLI = 1.020, RMSEA = 0.000, SRMR = 0.006) CFA for 8 to 10 years old group ($\chi2$ = 5.881, *p*= 0.053, CFI = 0.981, TLI = 0.943, RMSEA = 0.076, SRMR = 0.027).	**59%**

Nicola, Waugh, Charles & Russell (2018)	MABC-2	Final sample: n=59, aged 5–11 years (Females n = 28 and Males n = 31) The ABs were as follows: 3–6 years (n=19), 7–10 years (n=31); and 11–16 years (n=9)	Criterion Validity (Concurrent) MABC-2 in person and via telerehabilitation technology Hypothesis testing validity	Mean absolute difference (SD)	Aiming & Catching = 0.27 (2.07) Balance = 0.15 (2.59) Total Test Score = 0.03 (1.63)	**40%**
				Percentage Agreement	% Exact; % within 1 point; % within 2 points; % within 3 points Aiming & Catching = 26.67; 51.67; 71.67; 90 Balance = 31.67; 51.67; 71.67; 81.67 Total Test Score = 31.67; 66.67; 81.67; 100	
				Bland-Altman	Upper & Lower limits Aiming & Catching = 3.80, −4.33 Balance = 5.23, −4.93 Total Test Score = 3.22, −3.15	

				Paired samples T-test (95% Cl)	Aiming & Catching: TR vs in-person = 0.27 (SD = 2.09), (Cl = -0.82, 0.27), P = 0.32 Balance: TR vs in-person = 0.15 (DS = 2.61), (Cl= -0.53, 0.83), P = 0.66 Total test score: TR vs in-person = 0.03 (SD = 1.64), (Cl= -0.39, 0.46), P = 0.87	
Niemeijer, Van Waelvelde & Smits-Engelsman (2015)	MABC-2	1172 children within each age band: AB1 = 431 children AB2 = 333 AB3 = 408 (No further information)	Cross-cultural validity between Dutch and UK children	Independent t-tests	Aiming and Catching 1: Age band 1 – t= -0.22, p=.82 Age band 2 – t=4.40, p <.001 Age band 3 – t= 5.20, p<.001 Aiming and Catching 1 (other hand) Age band 3 – t= 5.30 p<.001 Aiming and Catching 2 Age band 1 – t= -0.85 p=.40 Age band 2 – t= 0.94 p= .35 Age band 3 – t= -0.25, p= .81	**61%**

					Balance 1 Age band 1 – t= 1.38 p=.17 Age band 2 – t=3.70, p <.001 Age band 3 – t=6.12, p<.001 Balance 1 (other leg) Age band 1 – t= 0.74, p= .46 Age band 2 – t= 4.65, p<.001 Balance 2 Age band 1 – t= -3.06, p= .002 Age band 2 – t= -0.07 p=.95 Age band 3 – t=6.33, p<.001 Balance 3 Age band 1 – t=3.26, p=.001 Age band 2 – t=3.05 p=.002 Age band 3 – t= 1.61, p=.11	

					<u>Balance 3 (other leg)</u> Age band 2 – t= 4.22, p<.001 Age band 3 – t=3.19, p=.002 <u>Aiming and Catching Total</u> Age band 1 – t= -0.72 p=.47 Age band 2- t=3.49, p <.001 Age band 3 – t= 4.64, p<.001 <u>Balance Total</u> Age band 1 – t=0.68, p=.50 Age band 2 – t=4.88, p<.001 Age band 3 – t=7.55, p<.001 <u>Total test score</u> Age band 1 – t= -0.91 p=.36 Age band 2 – t= 5.37, p <.001 Age band 3- t=7.04, p <.001	

Novak et al (2016)	KTK	2479 children aged between 6-11 years Females = 1179 and Males = 1300	Criterion Validity (Concurrent) (KTK 3 and KTK 4)	Pearson correlation	6 years: Boys: n = 135, r = 0.96** Girls: n = 166, r = 0.97** Total sample: n = 301, r = 0.96** 7 years: Boys: n = 228, r = 0.97** Girls: n = 195, r = 0.97** Total sample: n = 423, r = 0.97** 8 years: Boys: n = 250, r = 0.98** Girls: n = 236, r = 0.97** Total sample: n = 486, r = 0.97** 9 years: Boys: n = 276, r = 0.97** Girls: n = 280, r = 0.98** Total sample: n = 556, r = 0.98**	**56%**

					10 years: Boys: n = 214, r = 0.97** Girls: n = 148, r = 0.97** Total sample: n = 362, r = 0.97** 11 years: Boys: n = 197, r = 0.98** Girls n = 154, r = 0.98** Total sample: n = 351, r = 0.98** Total: Boys: n = 1300, r = 0.97** Girls: n = 1179, r = 0.97** Total sample: n = 2479, r = 0.97**	
				Chi-Squared, Cohens Kappa	Chi^2=6822.53, p<0.001; Kappa = 0.72	

Okuda, Pangelinan, Capellini & Moreira (2019)	MABC-2 and BOT-2	BOT-2: 187 elementary school students (grades 1 to 6) (mean age: 113 +- 20 months; boys: n = 117, 62.56%). SLD (n = 20; 10.7%) MABC-2 : 127 elementary school students (grade 1) (mean age: 76 =- 2 months; boys: n= 58, 45.67%).	Structural validity	Confirmatory factor analysis and bifactor analysis (CFA)	BOT-2 CFA with four dimensions were: $\chi2(14) = 20.937$, $p = 0.1135$; CFI = 0.988; TLI = 0.976; RMSEA = 0.050 (90% confidence interval [90%CI] = 0.000 to 0.093). Considering the bifactor model for BOT- 2: $\chi2(17) = 38.545$, $p = 0.0021$; CFI = 0.962; TLI = 0.938; RMSEA = 0.082 (90%CI = 0.048 to 0.117). MABC-2 CFA with three dimensions were: $\chi2(32) = 46.569$, $p = 0.0463$; CFI = 0.92; TLI = 0.89; RMSEA = 0.06 (90%CI = 0.008 to 0.095) Considering the bifactorial model for MABC-2: $\chi2(26) = 25.560$, $p = 0.4875$; CFI = 1.000; TLI = 1.004; RMSEA = 0.000 (90%CI = 0.000 to 0.069).	**65%**
Psotta & Abdollahipour	MABC-2	Two samples of children:	Structural Validity	Confirmatory Factor analysis	Age band 2 $\chi^2(30)=40.612$, p= 094,CMIN/df = 1.354, RMSEA =0.027, GFI = 0.980, AGFI= 0.964,TLI= 0.972	**69%**

(2017)		7- 10-year-olds (n = 484, 248 boys and 236 girls) 11-16-year-olds (n = 674, 328 boys and 346 girls)	Hypothesis testing validity		Additional factor loading of Bal 3o MD (-0.27, p<.0001) and MD 3 on AC (-0.28, p=.009) Age band 3 χ^{2}= 42.081, p=070, CMIN/df= 1.403, RMSEA= 0.024, GFI= 0.984, AGFI= 0.970, and TLI= 0.958.	
Re, Logan, Cattuzzo, Henrique, Tudela, & Stodden, (2018)	TGMD-2 and KTK	424 healthy children (47% girls and 53% boys) aged between 5 and 10 years old Demographics: White (62%), Black (13%)	Criterion Validity (Concurrent)	Pearson Correlation	5–6 years old: r = 0.52, r2 = 0.27 7–8 years old: r = 0.50, r2 = 0.25 9–10 years old: r = 0.34, r2 = 0.12	**69%**
				Paired sample t-test on percentile ranks	5–6 years: t= −3.029(157), p= .003 7–8 years: t= −11.134 (203) p <.001	

		"Mixed" (25%) The sample was grouped as follows: 5–6 years (n = 158, 76 girls; M age = 5.78, SD = 0.46 years), 7–8 (n = 204, 98 girls; M age = 8.03, SD = 0.54 years), 9–10 (n = 62, 27 girls; M age = 9.56, SD = 0.35 years)			9–10 years: t= −7.243 (61) p<.001 All: t= −11.711 (423), p <.001	
Rintala, Saakslahti	TGMD-3	60 Finnish children (aged	Intra-rater reliability	Kappa statistic	**Rater A**	**54%**

& Livonen (2017)		3-9 years old) divided into three separate samples of 20: Intra-rater reliability study: Rater A: Boys n = 10, (ages 6 to 9 years (M = 7.8 ± 1.2)), and Girls n = 10, (ages 5 to 9 years (M = 7.4 ± 1.2)) Rater B: Boys n = 8, (ages 4 to 7		Percentage agreement calculation Intraclass correlation coefficient (with upper and lower boundary)	Run: κ=0.58 Gallop: κ= 0.8 Hop: κ =0.51 Skip: κ =0.75 Horizontal jump: κ = 0.61 Slide: κ =0.58 Two hand strike on a stationary ball: κ =0.84 One hand force and strike on self-bounced ball: κ =0.70 One hand stationary dribble: κ =0.67 Two hand catch: κ = 0.90 Kick a ball stationary: κ = 0.62 Overhand throw: κ =0.84 Underhand throw: κ =0.85 Locomotor skills: κ =0.69 Ball skills: κ =0.77 Total skills: κ =0.75 **Rater B** Run: κ =0.42		

		years (M = 6.6 ± 1.4)), and Girls n = 12, (ages 3 to 7 years (M = 6.1 ± 1.6)) Additional inter-rater reliability sample: Boys n = 10, (ages 4 to 6 years (M = 5.9 ± 0.7)) and Girls n = 10, (ages 5 to 6 years (M = 6.2 ± 0.5))			Gallop: κ =0.77 Hop: κ =0.62 Skip: κ =0.86 Horizontal jump: κ =0.68 Slide: κ = 0.61 Two hand strike on a stationary ball: κ =0.47 One hand force and strike on self-bounced ball: κ =0.73 One hand stationary dribble: κ =0.72 Two hand catch: κ =0.81 Kick a ball stationary: κ= 0.76 Overhand throw: κ =0.68 Underhand throw: κ =0.84K Locomotor skills: κ =0.73 Ball skills: κ =0.73 Total skills: κ =0.73	
			Inter-rater reliability	Kappa, ICC	Run: κ =0.63 ICC= 0.63 Gallop: κ =0.62, ICC=0.61 Hop: κ =0.19 ICC=0.13 Skip: κ =0.87 ICC=0.87	

					Horizontal jump: κ =0.38 ICC=0.37 Slide: κ =0.45 ICC=0.45 Two hand strike on a stationary ball: κ =0.32K, ICC=0.32 One hand force and strike on self-bounced ball: κ =0.64 ICC=0.64 One hand stationary dribble: κ =0.81 ICC=0.81 Two hand catch: κ =0.84 ICC=0.84 Kick a ball stationary: κ =0.52 ICC=0.50 Overhand throw: κ =0.65 ICC=0.65 Underhand throw: κ =0.63 ICC=0.62 Locomotor skills: κ =0.57 ICC=0.56 Ball skills: κ =0.64 ICC=0.64 Total skills: κ =0.62 ICC=0.62	

Rosblad & Gard (1998)	MABC	60 children (Females = 28 and Males = 32). Ages ranging from 73 to 83 months (mean = 66 months) None of the children had any known disabilities.	Cross Cultural Validity (Sweden and America)	T-test	Ball skills: Catching bean bag (no. out of 10) P = 0.857 Rolling ball into goal (no. out of 10) P = 0.002 Static and dynamic balance: One-leg balance, preferred leg(s) P = 0.225 One-leg balance, non-preferred leg (s) P = 0.017 One-leg balance, right leg (s) P = 0.102 One-leg balance, left leg (s) P = 0.040 Jumping over cord (no. of trials to pass) P = 0.052 Walking heels raised (no. of steps) P = 0.861	**39%**
Rudd et al (2016)	TGMD-2 and KTK	In total 158 children aged 6-12 years old. (M age = 9.5 SD 2.2)	Structural validity KTK Hypothesis testing validity	Confirmatory Factor Analysis	Adequate model fit: $\chi2$ (2df) = 1.49, P = .47, $\chi2$/df = 0.75, CFI = 1.00, SRMR = .01, RMSEA = .01, P CLOSE = .60	**43%**

		Females = 72 Males = 86	Structural validity for the TGMD Hypothesis testing validity	Confirmatory Factor Analysis	Locomotor: $\chi2$ (9df) = 9.21; P = .42; $\chi2$/df = 1.02; CFI = .99; SRMR = .05; RMSEA = .01; PCLOSE = .69 Object control: $\chi2$ (9) = 27.54; $\chi2$/df = 1.34; P = .001; CFI = .80; SRMR = .07; RMSEA = .11; PCLOSE = .02 This original model was inadequate, so it was revised: $\chi2$ (8) = 10.13, P = .26; $\chi2$/df = 1.26; CFI = .98; SRMR = .04; RMSEA = .04; PCLOSE = .52 FMS hierarchical model: $\chi2$(52) = 71.07; P = .04; $\chi2$/df = 1.36; CFI = .86; SRMR= .07; RMSEA = .05; PCLOSE = .52 The effect of object control on overall fundamental movement skill = .67	

					The effect of locomotor on overall fundamental movement skill = .39	
			Inter-rater reliability	Bland-Altmann	Locomotor - 95% limit -0.7 to 0.7 Object control skills 95% limit -0.6 to 0.6. 95% confidence within one 1SD (1.96) and contains zero	
Ruiz et al (2003)	MABC	Spanish study: Total n = 385 (Females = 183 Males = 202) Japanese study: Total n = 102 Females = 49	Cross Cultural Validity	MANOVA	Age band 2 F= 25.07(16), p=.000 Age band 3 F= 35.73(16), p=.000	**25%**

		Males = 53 American Study: Total n = 521 Females = 284 Males = 237				
Schulz et al (2011)	MABC 2 Test	1172 children , aged 3–16 years. (Females = 606 Males = 566) AB1 n = 431 AB2 n = 333 AB3 n = 408	Structural validity	Confirmatory factor analysis	<u>Age band 1:</u> 3 correlated factors was rejected x2 (df = 32) = 410.65, p < 0.001 RMSEA = 0.17, NNFI = 0.76, AGFI = 0.70, SRMR = 0.19 3 factor plus general factor: x2(df = 24) = 33.44, p < 0.095, RMSEA = 0.03, NNFI = 0.99, AGFI = 0.96, SRMR = 0.023 <u>Age band 2:</u> 3 correlated factors was rejected x2 (df = 32) = 124.6, p < 0.001, RMSEA = 0.094, NNFI = 0.83, AGFI = 0.85, SRMR = 0.089	**62%**

					Double loadings for balance: x2 (df = 27) = 37.70, p = 0.08; RMSEA = 0.035, NNFI = 0.98, AGFI = 0.95, SRMR = 0.038 <u>Age band 3</u> 3 correlated factors was rejected x2 (df = 32) = 71.05, p < 0.001 RMSEA = 0.055, NNFI = 0.93, AGFI = 0.93, and SRMR = 0.056 Double loadings: x2 (df = 28) = 38.41, p = 0.09, RMSEA = 0.030, NNFI = 0.98, AGFI = 0.96, and SRMR = 0.036	
Simons et al (2008)	TGMD-2	In total 99 children aged 7-10 years with cognitive delay. Mean age = 8 years, 10 months (SD = 1 year, 9 months)	Structural validity Hypothesis testing validity	Confirmatory factor analysis	chi-square = 83.772, DF = 53, p = 0.004, GFI =.88, AFGI = .82.	**61%**
			Internal consistency	Cronbach's alpha	Locomotor α = .82 Object control α = .86	

		Females = 32 Mean age = 8 years, 8 months (SD = 10 months) Males = 67 Mean age = 9 years, 8 months (SD = 1 year, 2 months)			Gross Motor Quotient α = .90	
			Test-retest	Spearman correlation	Locomotor = .90 Object Control = .92 GMQ = .98	
			Inter-rater reliability	Pearson correlation	Locomotor = 1.00; p < .05 Object Control = 1.00; p < .05 GMQ = 1.00; p < .05	
Smits-Engelsman, Fiers, & Henderson (2008)	MABC (Dutch translation)	In total 9 children with movement difficulties (Females = 3,	Inter-rater reliability	Kappa	Average = .99	**50%**

		Males = 6) Ages ranged from 4 to 12 years of age				
Spironello, Hay, Missiuna, Faught, & Cairney (2010)	BOT (short form) and MABC	2278 children aged from 9 to 10 years old From the total sample, the study sample assessed on BOT-SF and M-ABC: n = 340	Criterion Validity (Concurrent)	Pearson correlation	r = .50, P < 0.01	**93%**
				KAPPA (relative Improvement Over Chance)	5th percentile: κ = .19 RIOC = 29.41% 15th percentile: κ = .29 RIOC = 46.8%	
Stearns, Wohlers, McHugh, Kuzik, & Spence (2019)	PLAYbasic and CAMSA	In total 102 children October 2014: N = 54	Inter rater reliability (for PLAYbasic and PLAYfun)	Intraclass correlation	PLAYbasic October 2014: Average measures =.84**, 95%CI = .73, 9.1 Single Measures = .72**, 95%CI= .57, .83	**43%**

		Mean age (SD) = 11.10 (1.36) Age Range = 8.98 to 13.85 Female = 28 (52%) Male = 26 (48%) March 2015: N = 48 Mean age (SD) = 11.48 (1.31) Age Range = 9.27 to 14.12 Female = 21 (44%) Male = 27 (56%)			March 2015: Average measures =.88**, 95%CI = .79, 9.4 Single Measures = .79**, 95%CI= .65, .88 <u>PLAYfun</u> October 2014 Average measures = .88***, 95%CI = .79,93 Single measures = .78***, 95%CI = .65,86 March 2015 Average measures = .90***, 95%CI = .82, .94 Single measures = .82***, 95%CI = .70, .89	
			Internal consistency (for PLAYbasic and PLAYfun)	Cronbach's alpha	<u>PLAYbasic</u> October 2014: Mean between raters = .61 Rater 1 = alpha .62 Rater 2 = alpha .65 March 2015: Mean between raters = .6	

					Rater 1 = .61 Rater 2 = .56 <u>PLAYfun</u> October 2014: Mean between raters = .87 Rater 1 = alpha .87 Rater 2 = alpha .86 March 2015: Mean between raters = .87 Rater 1 = alpha .87 Rater 2 = alpha .83	
			Criterion Validity (Concurrent) Hypothesis testing validity	Pearson correlation	<u>Between PLAYbasic and CAMSA</u> October 2014: Mean = .48** Rater 1 = .47** Rater 2 = .41**	

					March 2015: Mean = .51** Rater 1 = .40** Rater 2 = .61** Between PLAYfun and CAMSA October 2014: Mean = .51** Rater 1 = .47** Rater 2 = .50** March 2015: Mean = .58** Rater 1 = .51** Rater 2 = .60**	
Tan, Parker &	BOT-SF and MABC	In total 69 children	Criterion Validity (Concurrent)	Spearman rank	*r* = .79	**57%**

Larkin (2001)		(Females = 25, Males = 44) between the ages 4 years, 8 months to 10 years, 8 months (M = 81.8 months, SD = 19.4 months)				
Utesch et al (2016)	MOT 4-6	1467 children (aged between 3-6 years) Girls = 672 (45.8%) Boys = 795 (54.2%)	Structural validity	Rasch partial credit model	First-step analysis (all items of MOT 4-6) = *CR* =.032, *pCR* = .43; *P*- χ^2 = -.356, *pP*- χ^2 = .55 Follow-up model (global model fit with ordered threshold Parameters) = (*CR* = .1.964, *pCR* = .06; *P*- χ^2 = -.227, *pP*- χ^2 = .24, *RA* = .79) – five items removed	**79%**
				Mixed Rasch model	*CR* = 23, *pCR* = .28; *P*- χ^2 = -.53, *pP*- χ^2 = .7, *RA_class 1* = .63; RA_class 2 = .45	

Valentini (2012)	TGMD-2	In total 2,674 children (Females = 1322, Males = 1352 boys) Ages ranged from 3 to 10 years old (M age = 7.56 years, SD = 1.91 years)	Content validity	Content validity index	Clarity CVI = .93 Pertinence CVI = .91	**6**1%
				Exploratory factor analysis	RMSEA = .06, 90% CL [.06, .07] CFI (.88), NFI (.09), TLI (.83), GFI (.98), and AGFI (.95)	
			Test-retest reliability	Pearson correlation	Overall test: r = .9, p = .001 Locomotor subtest: r = .83, p = .0001 Object control subtest: r = .91, p = .0001 Run: r = .8, p = .001 Gallop: r = .51, p = .001 Hop: r = .57, p = .001 Leap: r = .54, p = .001 Horizontal jump: r = .76, p = .001 Slide: r = .71, p = .001 Striking stationary ball: r = .66, p = .001 Stationary dribble: r = .9, p = .001 Catch: r = .64, p = .001 Kick: r = .9, p = .001	

					Overhand throw: r = .72, p = .001 Underhand throw: r = .92, p = .001	
				T-test	Overall test: t=.9, p=.37 Locomotor subtest: t=.23, p=.82 Object control subtest: t=1.61, p=.11 Run: t=1.68, p=.09 Gallop: t=.73 p=.46 Hop: t=.98, p=.33 Leap: t=.33, p=.74 Horizontal jump: t=1.49, p=.14 Slide: t=1.65, p=1 Striking stationary ball: t=.5, p=.61 Stationary dribble: t=1.78, p=.08 Catch: t=.42, p=.68 Kick: t=2, p=.06 Overhand throw: t=.28, p=.78 Underhand throw: t=1.55, p=.12	

			Criterion Validity (Concurrent)	Pearson correlation	Percentiles for the total sample: $r = .27, p < .001$ The correlation explained 7.29% of the variance Percentiles for each age group: Age 4: $r = .42$, $p = .05$ Age 5: $r = .56$, $p = .002$ The associations explained 17.6% and 31.4% of the variance, respectively. Ages 6 to 10: $r = .14–.30, p > .05$ Children scored significantly higher on the MABC (M percentile=23.57; SD=24.57) compared with the TGMD-2 (M percentile = 7.50; SD = 10.23).	
				T-test	Total sample: $t(161) = −8.52, p < .001$ All age groups ($p< .007$)	
			Intra rater reliability	Cronbach's alpha	alpha = .92–.99	

			Inter rater reliability	Intraclass correlation	Locomotor subtest = .88 Object control subtest = .89 Locomotor skills = .86–.94 Object control skills = .87–.92	
Valentini, Ramalho, & Oliveira (2014)	MABC-2 (Portuguese translation)	In total 844 children (Females = 404 Males = 440) Aged between 3 and 13 years of age (M = 8.31, SD = 2.91) Demographics: 59.6% = White 40.4% = Non-white	Content Validity	Content validity index (%)	Clarity: Experts 1,2&3 = 71.8 Experts 1&2 = 93.9 Experts 1&3 = 78.9 Experts 2&3 = 74.3 Pertinence: Experts 1,2&3 = 99.2 Experts 1&2 = 99 Experts 1&3 = 99.3 Experts 2&3 = 98.5	**50%**
				Kappa	Clarity: Experts 1&2 (IC 95%) = .88 (.76-.99), p<.001	

					Experts 1&3 (IC 95%) = .80 (.65-.95), p=.001 Experts 2&3 (IC 95%) = .76 (.59-.93), p=.001 Pertinence: Experts 1&2 (IC 95%) = .92 (.83-.90), p<.001 Experts 1&3 (IC 95%) = .83 (.69-.98), p=.001 Experts 2&3 (IC 95%) = .87 (.59-.93), p<.001	
			Inter-rater reliability	Intraclass correlation	Manual dexterity: Raters A&B = .99 Raters A&C = .99 Raters B&C = .99 Raters A,B&C = .99 Ball skills: Raters A&B = .92 Raters A&C = .86 Raters B&C = .87 Raters A,B&C = .91	

					Balance: Raters A&B = .99 Raters A&C = .93 Raters B&C = .88 Raters A,B&C = .95 MABC-2 score: Raters A&B = .99 Raters A&C = .96 Raters B&C = .97 Raters A,B&C = .98	
			Intra-rater Reliability	Intraclass correlation	Manual dexterity: Rater Ax2 = .81 Ball skills: Rater Ax2 = .71 Balance: Rater Ax2 = .72	

					MABC-2 score: Rater Ax2 = .88	
			Structural Validity	Cronbach's alpha	Overall of the 3 subscales = .78 Manual Dexterity = .77 Ball skills = .52 Balance = .77	
			Criterion validity (predictive)	ANOVA	Significant differences among children identified with DCD, at risk for DCD and TD children (F (2,841) = 722.07, p < .0001, h2 = .63). Scores of TD children were significantly higher (p-values < .0001) Scores of children classified as at risk were significantly higher compared to the children with DCD (p-values < .0001).	

				ICC	ICC = .88; p < .007	
			Criterion Validity (Concurrent)	Pearson's correlation	TGMD-2 and MABC-2 standards scores =.30, p < .02 In each classification group: DCD = .54, p = .08 At risk for DCD = .26, p = .20 TD =.05, p = .40	
				Dependent t-tests	Children in general group: t (42) = 1.36, p < .18 Children within each classification group (p values range from .16 to .31)	
Valentini, Zanella, & Webster (2017)	TGMD-3 (Brazilian translation)	In total 597 children aged 3 to 10 Females = 302	Content validity	Content validity index (%)	Clarity: Experts 1,2&3 =78 Experts 1&2 = 97 Experts 1&3 = 77 Experts 2&3 = 75	**60%**

		(age: M = 6.58, SD = 2.06) Males = 295 (age: M = 6.76, SD = 2.11)			Pertinence: Experts 1,2&3 = 99 Experts 1&2 = 100 Experts 1&3 = 99 Experts 2&3 = 98	
				KAPPA concordanc e coefficient	Clarity: Experts 1&2 (IC 95%) = .91 (.88-1), p<.001 Experts 1&3 (IC 95%) = .79 (.62-.96), p=.001 Experts 2&3 (IC 95%) = .77 (.60-.94), p=.001 Pertinence: Experts 1&2 (IC 95%) = .97 (.88-1), p<.001 Experts 1&3 (IC 95%) = .86 (.72-.99), p=.001 Experts 2&3 (IC 95%) = .86 (.72-.99), p<.001	
			Inter-rater reliability	Intraclass correlation	TGMD-3 Total = .98 Locomotion = .95 Run = .85	

					Gallop = .91 Hop = .86 Skip = .99 Jump = .89 Slide = .93 Ball Skills = .97 Strike 1 hand = .96 Strike 2 hands = .94 Dribble = .97 Catch = .96 Kick = .86 Overhand throw = .96 Underhand throw = .97	
			Intra rater reliability	Intraclass correlation	TGMD-3 Total = .90 Locomotion = .90 Run = .61 Gallop = .71	

					Hop = .86 Skip = .81 Jump = .73 Slide = .78 Ball Skills = .85 Strike 1 hand = .73 Strike 2 hands = .68 Dribble = .90 Catch = .90 Kick = .69 Overhand throw = .60 Underhand throw = .72	
			Test-retest reliability	Pearson correlation	TGMD-3 Total = .90 Locomotion = .93 Run = .60 Gallop = .71	

					Hop = .82 Skip = .74 Jump = .67 Slide = .74 Ball Skills = .81 Strike 1 hand = .73 Strike 2 hands = .72 Dribble = .73 Catch = .86 Kick = .73 Overhand throw = .71 Underhand throw = .77	
			Internal consistency	Cronbach's alpha	TGMD-3-BR (α) = .74 Locomotion skills (α) = .63 Ball skills (α) = .76 Skill-to-test and -subtests by sex:	

					Boys (α) = .76, α values .72 to .76 Girls (α) = .74, α values .71 to .74 Subtests independently: Boys: Locomotion skills = .62, α values .59 to .62 Ball skills = .76, α values .72 to .76 Girls: Locomotion skills = .64, α values .61 to .64 Ball skills = .71, α values .68 to .71 Performance-criteria-to-test and –subtest: TGMD-3 = .93 Locomotion skills = .90 Ball skills = .88 Performance-criteria-to-test and -subtests by sex: TGMD-3-BR for boys = .93, α values .90 to .92 TGMD-3-BR for girls = .92, α values .92 to .92	

					Subtest independently Boys: Locomotion skills = .89, α values .87 to .89 Ball skills = .87, α values .85 to .87 Girls: Locomotion skills = .91, α values .89 to .91 Ball skills = .85, α values .83 to .85	
			Structural validity	Confirmatory factor analysis	Factor loading: Locomotion: Run = .46 Gallop = .41 Hop = .56 Skip = .44 Leap = no value Horizontal jump = .5 Slide = .6 Ball Skills: Strike 1 hand = .42 Strike 2 hands = .63	

					Dribble = .72 Catch = .58 Kick = .58 Overhand throw = .51 Underhand throw = .55 Run- SE=.03, skills-subtest correlation =.5** Gallop SE=.069, skills-subtest correlation =.62** Hop- SE=.053, skills-subtest correlation =.66** Skip- SE=.056, skills-subtest correlation =.62** Leap – no values Horizontal jump - SE=.045, skills-subtest correlation =.55** Slide – SE- NO VALUE, skills-subtest correlation =.73* Strike 1 hand - SE=.128, skills-subtest correlation =.6** Strike 2 hand- SE=.129, skills-subtest correlation =.7** Dribble - SE=.198, skills-subtest correlation =.76**	

					Catch- SE=.103, skills-subtest correlation =.62** Kick- SE=.108, skills-subtest correlation =.64** Overhead throw - SE=NO VALUE, skills-subtest correlation =.63** Underhand throw - SE=.105, skills-subtest correlation =.6**	
Valentini, Rudisill, Bandeira, & Hastie (2018)	TGMD-2	In total 2,463 children aged between 3 and 10 year olds (M = 8.10, SD = 1.32) Females= 1344 Males= 1119	Structural validity	CFA	Run *h*(communalities=.52), LOC=.54 Gallop *h*(communalities=.72), LOC=.83 Hop *h*(communalities=.57), LOC=.69 Strike *h*(communalities=.57), OC=.75 Kick *h*(communalities=.58), OC=.76 Throw *h*(communalities=.57), OC=.73 Two factors explained 59.33% of the variance (locomotor factor: 19.56%; object control factor: 39.76%). RMSEA (0.06, 90% confidence interval [0.06, 0.07]; CFI: 0.94; NFI: 0.94; TLI: 0.83; GFI: 0.98; and AGFI: 0.95	**61%**

			Internal consistency	Cronbach's alpha	Locomotion = .60 Run =.46 Gallop = .54 Hop =.37 Object control = .66 Strike = .54 Kick = .59 Throw = .55 General test = 0.70	
				Bivariate correlation (between activity and subtest)	Run = .64, p=<.001 Gallop = .59, p<.001 Hop = .7, p=<.001 Strike = .68, p<.001 Kick = .68, p<.001 Throw = .74, p<.001	

				Intraclass correlation	Locomotion = .67 Object control = .68 SF of TGMD = .71	
			Inter-rater reliability	Intraclass correlation	Locomotion: A&B = .94, A&C = .91, B&C = .92, A&B&C = .94 Run: A&B = .87, A&C = .81, B&C = .82, A&B&C = .87 Gallop: A&B = .94, A&C = .89, B&C = .83, A&B&C = .90 Hop: A&B = .92, A&C = .93, B&C = .92, A&B&C = .93 Object Control: A&B = .96, A&C = .93, B&C = .94, A&B&C = .96	

					Strike: A&B = .89, A&C = .83, B&C = .84, A&B&C = .89 Kick: A&B = .96, A&C = .90, B&C = .85, A&B&C = .92 Throw: A&B = .96, A&C = .95, B&C = .94, A&B&C = .95	
			Intra rater reliability	Intraclass correlation	Locomotion: A = .95, B = .96, C = .94 Run: A = .94, B = .97, C = .95 Gallop: A = .96, B = .97, C = .93 Hop: A = .96, B = .95, C = .95	

					Object Control: A = .97, B = .98, C = .96 Strike: A = .97, B = .99, C = .95 Kick: A = .96, B = .97, C = .96 Throw: A = .95, B = .96, C = .94	
			Test-retest reliability	Correlation analysis (not specified)	Locomotor r = .87 Run r = .84 Gallop r = .55 Hop r = .61 Object control r = .95 Strike r = .7	

					Kick r = .94 Throw r = .76	
Valentini et al. (2015)	TGMD-2 MABC	424 children (220 boys and 204 girls, age range: 4–10 years) DCD = 58 At risk of DCD = 133 TD = 233	Criterion Validity (Concurrent)	Pearson correlation	TGMD-2 Locomotor and MABC Ball Skills =.202 TGMD-2 Locomotor and MABC Balance =.187 TGMD-2 Locomotor and MABC Total =.169 TGMD-2 Object control and MABC Ball Skills =.289 TGMD-2 Object control and MABC balance =.207 TGMD-2 Object control and MABC Total =.316 TGMD-2 Total and MABC Ball Skills =.244 TGMD-2 Total and MABC Balance =.181 TGMD-2 Total and MABC Total =.226	33%

			Inter-rater Reliability (TGMD-2)	Pearson correlation	TGMD-2 locomotor r ranged from .88–.96; object control .89–.94 MABC manual dexterity: r = .96; ball skills: r = .94; balance: r = .97	
Valtr & Psotta (2019)	MABC-2	120 Czech participants of three age groups (17:0 – 17:11 years: months, 18:0-18:11 years: months, 19:0-19:11 years: months), n= 40 (20 boys, 20 girls) in each age group.	Structural Validity	Confirmatory factor analysis (CFA)	Age band 3 $\chi 2(9) = 14.035$, p= .121, CMIN/df= 1.559, RMSEA = .069, GFI = 0.966, AGFI = 0.920, and TLI = 0.954. All factor loadings on the MD or AC latent factor were statistically significant ($p < .05$).	**54%**
Van Waelvelde , De Weerdt, De Cock,	MABC (Dutch version) and tests of ball	Sample n = 90 children (50 = boys and 40 = girls)	Criterion Validity (Concurrent)	Spearman correlation	7-8 years: Total impairment score = -.72, p<.01 Speed of one hand = -.51, p<.01 Bimanual coordination = -.45, p<.01 Pen control= -40, p<.01	**66%**

& Smits-Engelsman, (2004)	catching and balance	Control n = 43 children (29 = boys and 14 = girls) The age groups are as follows: 7–8 years: N = 107, (71 from the sample group and 36 from the control group). Mean age = 8 years 6 months. 9–10 years:	(MABC & Ball catching)		Ball skills sub score = -.72, p<.01 Catching = -.74, p<.01 Throwing = -.58, p<.01 Balance sub score = -.46, p<.01 Standing on one leg = -.48, p<.01 Jumping = -.19 Balance in walking = -.21 9 years: Total impairment score = -.68, p<.01 Speed of one hand = -.30 Bimanual coordination = -.35 Pen control = -.60, p<.01 Ball skills sub score = -.53, p<.01 Catching = -.54, p<.01 Throwing = -.27 Balance sub score = -.48, p<.01 Standing on one leg = -.45, p<.01 Jumping = -.18 Balance in walking = -.51, p<.01	

		N = 26, (19 from the sample group and 7 from the control group). Mean age = 9 years 3 months.	Criterion Validity (Concurrent) (MABC & KTK jump)	Spearman correlation	7-8 years: Total impairment score = -.76, p<.01 Speed of one hand = -.54, p<.01 Bimanual coordination = .47, p<.01 Pen control= -.52, p<.01 Ball skills sub score = -.5, p<.015 Catching = -.57, p<.01 Throwing = -.44, p<.01 Balance sub score = -.70, p<.01 Standing on one leg = -.65, p<.01 Jumping = -.41, p<.01 Balance in walking = -.37, p<.01 9 years: Total impairment score = -.69, p<.01 Speed of one hand = -.43, p<.05 Bimanual coordination = -.39, p<.05 Pen control = -.47, p<.05 Ball skills sub score = -.58, p<.01 Catching = -.44, p<.01 Throwing = -.49, p<.01 Balance sub score = -.65, p<.01	

					Standing on one leg = -.48, p<.05 Jumping = -.33 Balance in walking = -.58, p<.01	
			Criterion Validity (Concurrent) (MABC & KTK beam)	Spearman correlation	7-8 years: Total impairment score = -.72, p<.01 Speed of one hand = -.57, p<.01 Bimanual coordination = .43, p<.01 Pen control= -.46, p<.01 Ball skills sub score = -.52, p<.01 Catching = -.53, p<.01 Throwing = -.38, p<.01 Balance sub score = -.68, p<.01 Standing on one leg = -.63, p<.01 Jumping = -.30, p<.01 Balance in walking = -.46, p<.01 9 years: Total impairment score = -.58, p<.01 Speed of one hand = -.37 Bimanual coordination = -.19 Pen control= -.20	

					Ball skills sub score = -.34 Catching = -.34 Throwing = -.26 Balance sub score =-.69, p<.01 Standing on one leg = -.66, p<.01 Jumping = -.50, p<.01 Balance in walking = -.38	
Wagner, Webster & Ulrich (2017)	TGMD-3 (German translation)	In total 189 typically developing children (Females = 90, Males = 99) Mean age = 7.15 years (SD = ± 2.02 years Age Range = 3.17-10.67 years	Test-retest reliability Hypothesis testing validity	Intraclass correlation	Locomotor skills = .94, 95% CI [.91, .96], p < .001 Balls skills = .98, 95% CI [.97, .99], p < .001	**70%**
			Inter-rater reliability Hypothesis testing validity	Intraclass correlation	Locomotor skills = .88, 95% CI [.76, .95], *p* < .001 Ball skills = .97, 95% CI [.94, .99], *p* < .001	
			Intra-rater reliability	Intraclass correlation	Locomotor skills = .97, 95% CI [.94, .99], *p* < .001	

		56 = kindergarten children 133 = elementary school children	Hypothesis testing validity		Ball skills = .99, 95% CI [.98, 1.00], *p* < .001	
			Internal consistency Hypothesis testing validity	Cronbach's alpha	Locomotor skills = .76 Ball skills = .89	
			Structural validity Hypothesis testing validity	Confirmatory factor analysis	Locomotion: Run: IR = .32 Gallop: IR = .17 One legged hop: IR = .47 Skip: IR =.42 Horizontal jump: IR = .37 Slide: IR = .47 Ball skills: One hand forehand strike: IR = .69 One hand stationary dribble: IR = .63	

					Two hand catch: IR = .44 Kick a stationary ball: IR = .63 Overhand throw: IR = .63 Underhand throw: IR = .52 Divergent measures: Locomotor: FR=.77, AVE=.38, FLR = 1.77 Ball skills: FR= .90, AVE =.62, FLR = 1.09	
			Criterion Validity (Concurrent) Hypothesis testing validity	Spearman correlation	Ball skills: At time of testing = *rs*(89) = .36, $p < .001$ 12 months after = *rs*(66) = .39, $p < .001$ Locomotor: At the time of testing - *rs*(89) = .15, $p = .086$, *1-ß* = .42 12 months after= *rs*(66) = .08, $p = .253$, *1-ß* = .16	
Ward, Thornton, Lay, Chen	TGMD-2	16 primary school students (age	Inter-rater reliability	ICCs and Spearman	<u>All assessments Overall ICC (Video):</u> Rater 1 (Pediatric professionals) = .88**(95% CI = 0.80-0.93) Rs = 0.75**	**43%**

& Rosenberg (2020)		8.2 ± 2.2 years)and 17 raters were recruited to the current study; 7 pediatric movement professionals (age 28.7 ± 6.55 years) and 10 primary school teachers (age 34.5 ± 13.5 years).	Hypothesis testing validity	correlations (Rs)	Rater 2 (Primary teachers) = .84** (95% CI =0.75–0.90) Rs = .73** <u>All assessments Overall ICC (Point light):</u> Rater 1 = .87**(95% CI 0.79–0.93) Rs = 0.79** Rater 2 = .85** (95% CI 0.77–0.91) Rs = .67** <u>Individual Skills (Video):</u> Kick ICC Rater 1 = .92** (95% CI = .80- .98) Rater 2 = .87** (95% CI = .71- .96) Throw ICC Rater 1 = .92** (95% CI = .80- .98) Rater 2 = .89** (95% CI = .74 -.97) Hop ICC Rater 1 = .86** (95% CI = .67 - .96) Rater 2 = .80** (95% CI = .53 - .91) Jump ICC Rater 1 = .75** (95% CI = .42 - .93) Rater 2 = .59** (95% CI = .05 - .88) <u>Individual Skills (Point light):</u> Kick ICC	

					Rater 1 = .92** (95% CI = .80- .98) Rater 2 = .86** (95% CI = .69- .96) Throw ICC Rater 1 = .94** (95% CI = .86- .98) Rater 2 = .90** (95% CI = .78 -.97) Hop ICC Rater 1 = .74** (95% CI = .39 - .93) Rater 2 = .72** (95% CI = .35 - .92) Jump ICC Rater 1 = .86** (95% CI = .68 - .96) Rater 2 = .71** (95% CI = .34 - .92)	
Wagner, Kastner, Petermann, & Bos (2011)	MABC-2	In total 323 children (Female = 154, Male = 169) Mean age of 8.96 years (min: 7.02, max: 10.98).	Structural validity	Confirmatory factor analysis	Aiming and catching: Factor reliability = .43 and average assessed variance = .28 Throw tennis: Indicator reliability = .15 Throw beanbag: Indicator reliability = .44, t(factor loading) = 2.89 Balance: Factor reliability = .53 and average assessed variance = .45 One foot: Indicator reliability = .46 WAL: Indicator reliability = .29, t(factor loading) = 6.04	**62%**

					Hop: Indicator reliability = .08, t(factor loading) = 4 Divergent measures: Average assessed variance: Manual dexterity = .44 Aiming and catching = .28 Balance = .45 Maximum squared intercorrelation: MD & BL = .55 BL & AC = .28 Fornell-Larcker Ratio: MD = 1.25 AC = 1.01 BL = 1.22	
Wilson, Kaplan, Crawford, & Dewey (2000)	BOT-LF	In total 50 children aged between 7 years, 1 month and 14	Inter-rater reliability	Intraclass correlation	Entire sample: Battery composite ICC = .945 Gross motor composite ICC = .897	**53%**

		years, 5 months (M = 10.34 years, SD = 1.83). Male = 33 Female = 17 26 children had known learning or attentional problems (LD) or both. 24 children did not have any known learning problems.			LD: Battery composite ICC = .939 Gross motor composite ICC = .898 Non LD: Battery composite ICC = .892 Gross motor composite ICC = .853 DCD: Battery composite ICC = .939 Gross motor composite ICC = .816 Non DCD: Battery composite ICC = .934 Gross motor composite ICC = .902 Running speed and agility = .902 Balance = .817 Bilateral motor coordination = .93 Strength = .84	

					Upper Limb coordination = .825	
				KAPPA	Battery composite = .64 Gross motor composite = .7	
Wuang & Su (2009)	BOT-2	Final sample (n = 100). Female = 41 and Male = 59 Average age = 82.9 months S.D. = 24.9, Age Range = 48–124 months. 64 children = mild ID 36 children = moderate	Internal consistency	Cronbach's alpha	Upper limb coordination = .87 Bilateral coordination = .87 Balance = .85 Running speed and agility = .87 Strength = .85 Manual coordination = .88 Body coordination = .87 Strength and agility = .88 TOTAL = .920	**57%**
			Test-retest reliability	Intraclass correlation (with a 2-way random effects model)	Upper limb coordination (95%CI) = .88 (.83 - .92) Bilateral coordination (95%CI) = .96 (.95 - .98) Balance (95%CI) = .99 (.98 - .99) Running speed and agility (95%CI) = .97 (.95 - .97) Strength (95%CI) = .96 (.95 - .97)	

		to severe ID			Manual coordination (95%CI) = .98 (.97 - .99) Body coordination (95%CI) = .99 (.98 - .99) Strength and agility (95%CI) = .99 (.97 - .99) TOTAL (95%CI) = .99 (.99 - 1)	
				Standard error of measureme nt	Upper limb coordination = .73 Bilateral coordination = .65 Balance = .49 Running speed and agility = .49 Strength = .63 Manual coordination = .66 Body coordination = .8 Strength and agility = .8 TOTAL = 1.79	
Wuang, Su & Su (2012)	MABC-2	The final sample (n=144) Females = 57 Males = 87	Internal consistency	Cronbach's alpha	Aiming and Catching = .84 Balance subscales = .88 MABC-2 Test total score: a = .90	**51%**

		Mean age = 7 years 7 months (SD 2y 1mo, range 6y–12y 9mo)				
			Test-retest reliability	Intraclass correlation (with a two-way random effects model)	AC1 = .88, 95%CI = .83 - .92, SEM = .74 AC2 = .96, 95%CI = .95 - .98, SEM = .61 AC OVERALL = .91, 95%CI = .82 - .95, SEM = .92 BL1 = .99, 95%CI = .98 - .99, SEM = .35 BL2 = .97, 95%CI = .95 - .98, SEM = .44 BL 3 = .96, 95%CI = .95 - .97, SEM = .62 BL TOTAL = .97, 95%CI = .95 - .98, SEM = .52 TOTAL SCORE = .97, 95%CI = .96 - .98, SEM = .52	
Wuang, Lin & Su (2009)	BOT-2	446 children with intellectual deficits aged 4-18 years Female = 40.4% Male = 59.6%	Structural validity	Rasch analysis (partial credit model) (IRT)	<u>Original BOT</u> 18/53 misfitting items Manual coordination PSI = 4.14 (0.95) Body Coordination PSI = 2.02 (0.80) Strength and Agility PSI = 4.24 (0.95) BLC4 and BAL 5 had disordered thresholds	**69%**

		Mean age was 9.4 years (S.D. = 4.02) 71.7% of children = classified as having mild ID 28.3% of children = classified as having moderate to severe ID			14 items had disordered step difficulty, so items were re-scored <u>Revised BOT</u> No misfitting items 99.8% of the variance accounted for No DIF for age or gender Unidimensional underlying construct	
Zhu et al (2011)	PE Metrics	5021 students Male = 2568 (51.1%) Female = 2453 (48.9%)	Structural validity	Many-faceted rasch model (IRT) Grade 2 analysed first - K and	All Infit and Outfit statistics of G2, K and G5 within acceptable “–2 to 2” range Acceptable age progression	**43%**

		The sample was split into: K = 1465, G2 = 1991 G5 = 1565		G5 anchored onto G2 scale		
Zoia et al (2018)	MABC-2 (Italian translation)	IT sample: AB1: 338 children between the ages of 3 and 6 years 162 females and 176 males AB2: 380 children between the ages of 7 and 10 years 199 females and 181 males	Structural Validity	Confirmatory Factor analysis	AGE BAND 1: Satorra-Bentler X2 (df = 23) = 57.42, p < .01, RMSEA = .067 (p = .096), NNFI = .96, AGFI = .93, SRMR = .054 All model parameters significant (t-value > 1.96) AGE BAND 2: Satorra-Bentler X2 (df = 30) = 78.46, p < .01, RMSEA = .065 (p = .073), NNFI= .95, AGFI = .92, SRMR = .067 All model parameters significant (t-value > 1.96)	**46%**
			Cross cultural validity (Italy and UK)	ANOVA	Country effect 11/27 raw scores (p < .01), ES low to moderate (ηp2: .014 - .09) Age Band 1	

		UK sample: AB1: 431 children, aged 3 to 6 years AB2: 333 children aged 7 to 10 years		(Bonferroni and LSD adjustment)	AC1 in 3-4 years (F(1,414) = 9.536; p = .002), interaction effect (F(1,414) = 4.103; p = .043): at 3 years of age, IT children made fewer catches (F(1,414) = 10.985, p = .001; Cohen's d: .48) Dynamic BAL1 (F(1,762) = 42.76; p < .001) IT children made less correct steps <u>Age band 2</u> AC1 (F(1,319) = 31,659; p < .001): IT children achieved a higher number of correct catches Static BAL both legs (best leg: F(1,705) = 13,581; p < .001; other leg: F(1,705) = 21,675; p < .001), IT children maintained balance longer Dynamic BAL1 (F(1,705) = 32,423; p < .001), Age X Country (F(3,705) = 4.270; p = .005): better result for UK children Dynamic BAL2 'other leg' (F(1,705) =	

					12,768; $p < .001$), IT children made a higher number of correct hops	
Zuvela, Bozanic, & Miletic (2011)	FMS POLYGON TGMD-2	95 children (48 boys and 47 girls) aged 8 years old (8.1 ± 0.3)	Intra-rater reliability	Intraclass correlation	Tossing and catching a volleyball against the wall consecutively = .92 Running across obstacles = .96 Carrying the medicine balls = .90 Straight running = .95 Overall test = .98	**42%**
			Structural validity	Factor analysis	Tossing and catching a volleyball against the wall consecutively: mean = 5.57, SD = 1.24, F = .84 Running across obstacles: mean = 4.91, SD = .59, F = .87	

					Carrying the medicine balls: mean = 5.33, SD = .59, F = .86 Straight running: mean = 4.53, SD = .31, F = .83	
			Criterion Validity (Concurrent) Hypothesis testing validity	Pearson's r correlation	r= -.82, p < .05	

Appendix D

Online Questionnaire used in Chapter 3

Primary School Teachers' Knowledge and Perceptions of Childhood Fundamental Movement Skills

Start of Block: Default Question Block

Q1 **Information for potential participants**

The purpose of this study is to: (1) investigate primary school teachers' knowledge and understanding of fundamental movement skills (2) explore the primary school teachers' perceptions of assessing pupils' motor skills in schools. As a primary school teacher you are invited to participate in the study, which will entail you completing a short questionnaire which will take approximately 10 minutes. All questions are optional, and you can refuse to answer a question by leaving the response field blank. Upon completion of the questionnaire you will have the option to enter a prize draw to win one of three £20 Amazon vouchers by leaving your email address. This email address will only be used to contact the winners of the prize draw.

Please be aware that if you leave the questionnaire part way through, your responses will not be saved, unless you click 'continue later'. This will save your responses up to that point and allow you to complete the rest of the questionnaire at a later date. You can withdraw your data from the study up to one month after completing the questionnaire by contacting one of the researchers (contact details listed below). All personal information will be kept confidential and all data will be anonymised to ensure that individuals are not identifiable. At the start of the questionnaire, you will be allocated a unique 4 digit ID number. This will be used to identify your responses in place of your personal information. Please keep a record of this number as the researchers will need this if you decide that you would like to withdraw from the study after completing the questionnaire.

If you have any questions, or would like any further information please contact: Lucy Eddy (L.Eddy@leeds.ac.uk), Dr Liam Hill (L.J.Hill@leeds.ac.uk / 0113 343

5726) or Dr Daniel Bingham (Daniel.Bingham@bthft.nhs.uk / 01274 383935).

This research has been approved by the School of Psychology Ethics Committee at the University of Leeds (insert ref number and approval date when approved).

◯ Yes (23)

◯ No (24)

Page Break

Display This Question:

If Information for potential participants The purpose of this study is to: (1) investigate primary s... = Yes

Q2 **Information for potential participants (part 2)**

Do you understand that you can withdraw your data up to one month after completing the questionnaire by contacting one of the researchers involved in this project?

Lucy Eddy (L.Eddy@leeds.ac.uk)
Dr Liam Hill (L.J.Hill@leeds.ac.uk)
Dr Daniel Bingham (Daniel.Bingham@bthft.nhs.uk)

◯ Yes (1)

◯ No (2)

Page Break

Display This Question:

If Information for potential participants The purpose of this study is to: (1) investigate primary s... = No

And Information for potential participants (part 2)Do you understand that you can withdraw your data... = No

Q3 Sorry, you are unable to take part in this questionnaire.

Skip To: End of Survey If Sorry, you are unable to take part in this questionnaire.() Is Displayed

Page Break

Q4 **Your unique ID number is listed below:**

rand://int/1000:9999

Please keep a record of this.

Q5 What is your age?

- 18-25 years old (1)
- 26-35 years old (2)
- 36-45 years old (3)
- 46-55 years old (4)
- 56-65 years old (5)
- 66+ years old (6)

Q6 What is your sex?

- ◯ Male (1)
- ◯ Female (2)
- ◯ Prefer not to say (3)
- ◯ Other (please specify) (4)

____

Q7 What is your job description?
(Please tick those which apply)

- ▢ Teacher (1)
- ▢ Teaching Assistant (2)
- ▢ Headteacher (3)
- ▢ Special Educational Needs Coordinator (SENCO) (4)
- ▢ Other (please specify) (5)

____

Skip To: Q9 If What is your job description? (Please tick those which apply) = Headteacher

Q8 What age are the pupils that you teach?
(Please tick all the ages that apply)

- ▢ 4-5 years old (1)
- ▢ 5-6 years old (2)
- ▢ 6-7 years old (3)
- ▢ 7-8 years old (4)
- ▢ 8-9 years old (5)
- ▢ 9-10 years old (6)
- ▢ 10-11 years old (7)

Q9 How long have you held a teaching job for?

- ○ Years (1) ____
- ○ Months (2) ____

Q10 What country do you currently teach in?

▼ Afghanistan (1) ... Zimbabwe (1357)

Q11 What type of school do you currently teach in?

- ○ State (1)
- ○ Private (2)
- ○ Academy (3)
- ○ Grammar (4)
- ○ Other (please specify) (5) ____

Q12 What is the highest level of qualification you have achieved?

- ○ GCSE (or equivalent) (1)
- ○ AS Level (or equivalent) (2)
- ○ A Level (or equivalent) (3)
- ○ Undergraduate degree (4)
- ○ Master's degree (5)
- ○ Professional degree (e.g. PGCE) (6)
- ○ Doctoral degree (7)

Q13 What is the general subject area of your highest qualification?
(e.g. Psychology, Education, Sport etc)

____

Page Break

Q14 Have you had any training on 'Fundamental Movement Skills'?

◯ Yes (1)

◯ No (2)

Skip To: Q17 If Have you had any training on 'Fundamental Movement Skills'? = No

Skip To: Q15 If Have you had any training on 'Fundamental Movement Skills'? = Yes

Q15 What training did you receive?

____

Q16 When did you complete this training?

____

Q17 How knowledgeable do you think you are about motor skills that are defined as 'Fundamental Movement Skills'?

◯ Not knowledgeable at all (1)

◯ Slightly knowledgeable (2)

◯ Moderately knowledgeable (3)

◯ Very knowledgeable (4)

◯ Extremely knowledgeable (5)

Q18 Which of the following motor skill do you think comprise 'Fundamental Movement Skills'?
(please tick all that apply)

- ☐ Running (1)
- ☐ Handwriting (2)
- ☐ Hopping (3)
- ☐ Jumping (4)
- ☐ Using cutlery (5)
- ☐ Balancing (6)
- ☐ Dressing oneself (7)
- ☐ Throwing (8)
- ☐ Catching (9)
- ☐ Walking (10)
- ☐ Crawling (11)
- ☐ Kicking (12)
- ☐ Brushing teeth (13)
- ☐ Riding a bike (14)
- ☐ Swimming (15)

Q19 On a scale of 1-5, to what extent do you think the development of fundamental movement skills has an impact upon:

	No Impact 1	2	3	4	High Impact 5
Academic achievement? ()					
Participation in physical activity? ()					
Mental health? ()					
Physical health? ()					
Social relationships? ()					

Q20 On a scale of 1-5, how confident are you that you could demonstrate the following activities:

	Not confident at all 1	2	3	4	Extremely confident 5

Running between two markers for 15 seconds ()	
Throwing beanbags into a target box two metres away ()	
Hopping between two markers one metre apart ()	
Holding a balance (e.g. standing on one leg) whilst passing a beanbag around your body ()	

Q21 On a scale of 1-5, how confident are you that yourself and one other member of staff could assess five children simultaneously in the following activities:

Not confident at all Extremely confident

1 2 3 4 5

Running between two markers for 15 seconds ()	
Throwing beanbags into a target box ()	
Hopping between two markers ()	
Balancing whilst passing a beanbag around their body ()	

Page Break

Q22 Do you/your school currently assess fundamental movement skill proficiency?

- ◯ Yes (1)
- ◯ No (2)
- ◯ Unsure (3)

Q23 Do you think the senior leadership team at your school would be supportive if you wanted to assess fundamental movement skill proficiency in your class?

- ◯ Definitely yes (1)
- ◯ Probably yes (2)
- ◯ Probably not (3)
- ◯ Definitely not (4)

Q24 Would you be able to access support from another member of staff (e.g. teaching assistant) to help you deliver an assessment of fundamental movement skills to a whole class?

- ◯ Definitely yes (1)
- ◯ Probably yes (2)
- ◯ Probably not (3)
- ◯ Definitely not (4)

Q25 Does your school have the following equipment:

	Yes (1)	No (2)	Unsure (3)
25 beanbags? (1)	○	○	○
Chalk? (2)	○	○	○
A sports hall larger than 5m x 5m? (3)	○	○	○
Outdoor space larger than 5m x 5m? (4)	○	○	○
Stopwatch? (5)	○	○	○
Tape measure or metre ruler? (6)	○	○	○

Q26 Over the course of a single school week, once per academic year, how long do you think is acceptable to spend assessing the fundamental movement skills of one class?
(please drag ***one*** *response into* ***each*** *of the boxes below)*

Per child	For a whole class
______ < 10 minutes (1)	______ < 10 minutes (1)
______ 10-30 minutes (2)	______ 10-30 minutes (2)

_______ 30-60 minutes (3)	_______ 30-60 minutes (3)
_______ 60-90 minutes (4)	_______ 60-90 minutes (4)
_______ Up to 2 hours (5)	_______ Up to 2 hours (5)
_______ 2 - 3 hours (6)	_______ 2 - 3 hours (6)
_______ 3 hours + (7)	_______ 3 hours + (7)

Q27 Do you think you have would be able to make time in the curriculum to spend two hours at the start of the school year evaluating your class' fundamental movement skills?

- Definitely yes (32)
- Probably yes (33)
- Probably not (34)
- Definitely not (35)

Q28 What time of the day would you be most likely be able to find time to assess fundamental movement skills?
(Please rank from the most likely to the least likely by dragging the responses)

_______ Physical Education (P.E.) lessons (1)
_______ Core lessons (Maths, English and Science) (2)
_______ Other lessons (e.g. Languages and Art) (3)
_______ After school (4)
_______ Before school (5)

Page Break

Q29 Do you think a school based assessment of fundamental movement skills has the ability to identify children who need additional support?

- ◯ Yes (1)
- ◯ No (2)
- ◯ Maybe (3)

Q30 On a scale of 1-5, how beneficial to your teaching would it be to have knowledge about your pupils' fundamental movement skills?

	Not beneficial at all				Extremely beneficial
	1	2	3	4	5
()					

Q31 Do you think that assessing childhood fundamental movement skills in school would increase your workload stress?

- ◯ Definitely yes (38)
- ◯ Probably yes (39)
- ◯ Probably not (40)
- ◯ Definitely not (41)

Q32 On a scale of 1-5, if you had training and support available, how likely would you be to assess the fundamental movement skills of the children in your class?

	Not at all				Extremely likely
	1	2	3	4	5
()					

Q33 How likely would your decision regarding whether to assess the fundamental movement skills be influenced by the opinions of other teachers in your school?

- ◯ Extremely likely (1)
- ◯ Somewhat likely (2)
- ◯ Neither likely nor unlikely (3)
- ◯ Somewhat unlikely (4)
- ◯ Extremely unlikely (5)

Page Break

Q34 Thank you for completing the questionnaire. If you would like to be entered into a prize draw to win one of three £20 Amazon vouchers please leave your email address below*.

* Your email address will not be downloaded from this website, and will **only** be used to contact you if you have won.

____

End of Block: Default Question Block

Appendix E
Teacher Manual used in Study 3 in Chapter 4

Lucy Eddy [ps13lhe]
UNIVERSITY OF LEEDS |

About FUNMOVES

FUNMOVES is a tool designed to **assess fundamental movement skills** in children. It specifically focuses on a number of motor skills that are central to childhood development: running, jumping, hopping, throwing, kicking and balancing.

Why are fundamental movement skills important?

Research has shown that children who have **poor fundamental movement skills** have an **increased risk** of adverse outcomes in childhood including **physical and mental health problems**, as well as **poor academic achievement**. Identifying children who struggle with key motor skills will help schools to target support effectively for those pupils.

Why should I use FUNMOVES?

FUNMOVES is an **evidence-based** assessment tool which has been **modified** based on the **teacher feedback** to ensure that it is feasible for use in schools. FUNMOVES is a fast way to identify children in your school which may need additional support – it can assess a whole class in two PE lessons. After completing the assessment, you will receive **tailored reports** on how each child performed compared to other children in the same year group.

Preparing for FUNMOVES

Resources Required

- 25 beanbags
- 80m electrical tape / chalk
- 6 response sheets
- 5 team score sheets
- A measuring tape or meter ruler
- A stopwatch or a device able to time activities
- Pens
- The help of a second member of staff to score activities

Splitting your class into teams

1. **Separate your class into groups of five, based on their ability**
   When you are splitting them into groups you should consider how good each child is at running, jumping, hopping, throwing, kicking and balancing.
2. **Complete the demographic information on the response sheet**
   Dominant hand should be noted as the hand they write with. You should state that you think a child has a motor problem if they have difficulty with handwriting, are clumsy when moving around the classroom, or has difficulty physically interacting with objects.

	Name 1	Name 2	Name 3	Name 4	Name 5

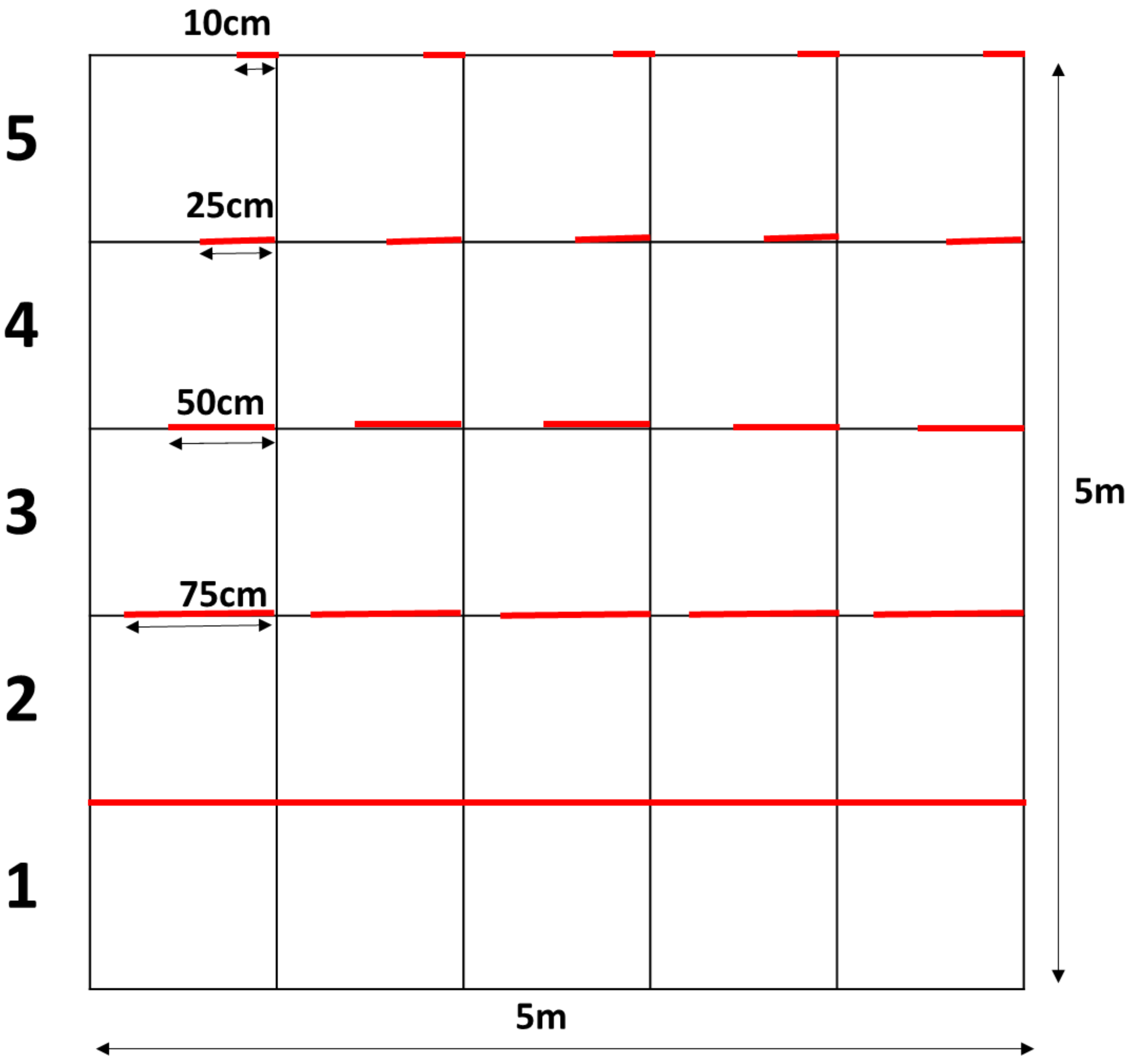
Demographics

Gender					
Date of Birth					
Dominant Hand					
Do you think this child has motor problems?					

3. **Compile teams**
   All the children whose names are written under name 1 will be a team, all the children who are in the name 2 column make up a team etc.
4. **Choosing team names**
   Once the teams are established, you should give each team a team score sheet, on which they can write their names and decide upon a team name.

Setting up the grid

All activities are based within a 5x5 metre grid, which should be set up using electrical tape or chalk and a tape measure to the specifications shown below. Please note the red lines on the diagram should be marked out in a different colour to the rest of the grid. Make sure there is space at the bottom of the grid for your class to sit in their



teams.

•

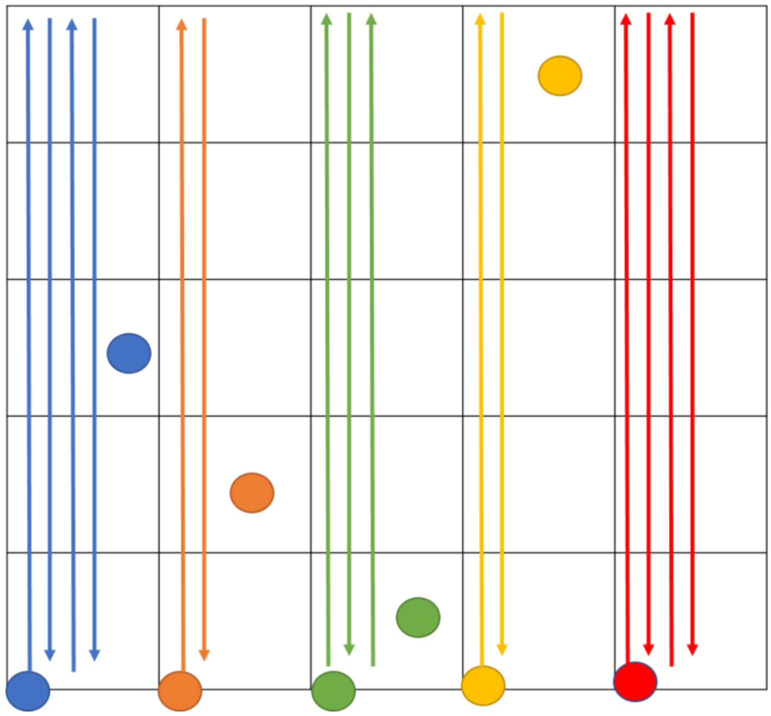
Implementing FUNMOVES

Team Competition

FUNMOVES can be run as a **team competition** to make it fun and engaging. A class can complete the assessment in approximately **1 hour**, and can be split up over a number of **PE lessons**.

* Give each team a score sheet and a pen so they can count up the number of points they get
* Before you begin testing, line up the children in their teams, in the box on your response sheet which corresponds to the lane on the grid
* Go through the activities one at a time, testing all children before moving to the next activity
* Do not allow children to practice the tasks before testing
* To avoid children not completing the tasks properly, tell them that they will not receive any points for their team if they cheat
* Try not to make it obvious when a child has been unsuccessful at completing a task, or if a child is 'winning'
* Mark down unsuccessful attempts on the response sheet, but allow the children to carry on and complete all activities, regardless of the level they achieved

Running



Circles represent children sat down:
Blue child – 4 points + Box 3
Orange child – 2 points + Box 2
Green child – 3 points + Box 1
Yellow child – 2 points + Box 5
Red child – 4 points

Rules

* Children have **15 seconds** to run as many times from the start line to the far line and back as possible
* When you say **STOP**, they have to **sit down** as quickly as possible facing the way they were running
* **Foot** must **touch** both the start **line** and the far line of the grid for them to get any points

Demonstrate the activity and explain the rules

Scoring

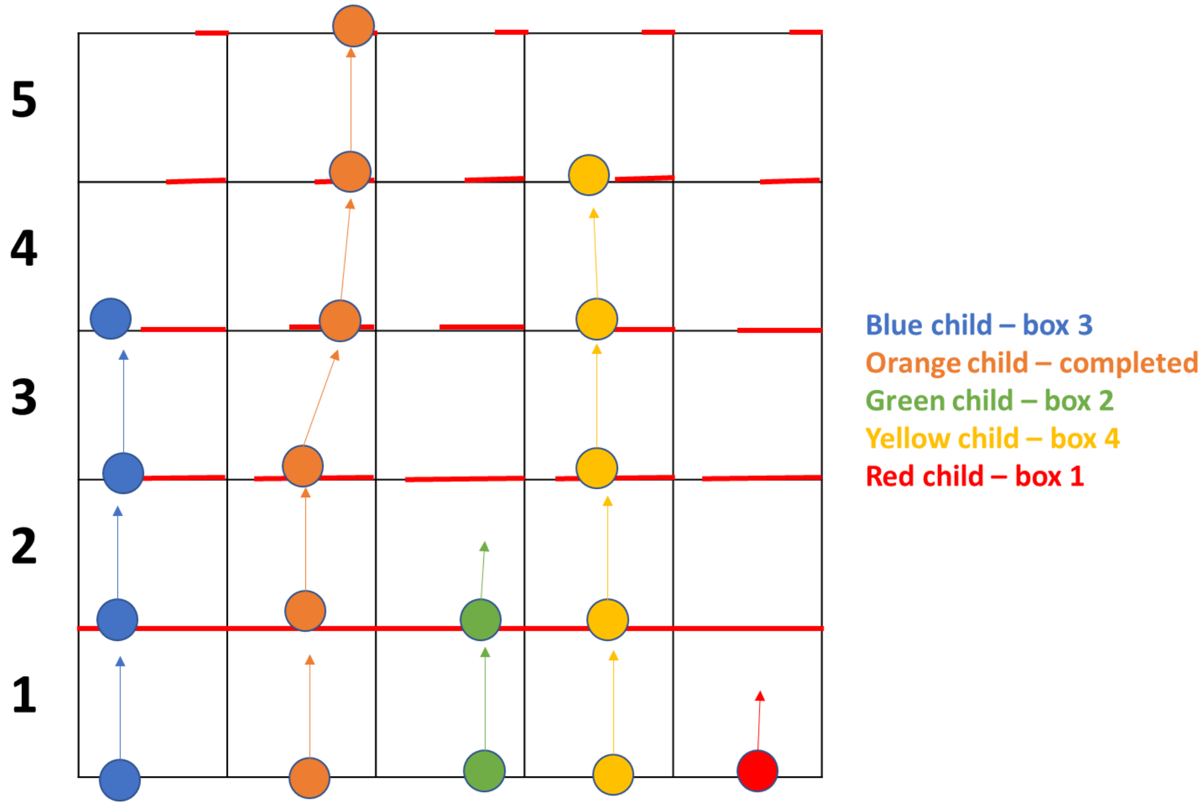
Running

Number of Full Lengths					

Children are scored by the number of '**full lengths**' they have run

* A **full length** comprises a **5 metre** run (from one side of the grid to the other)

Jumping



Rules

* Children **jump** to the first line, then pause
* Children are not allowed to jump line to line, they must use **small jumps**
* When all five children reach the line, count **3 seconds**, and then set them off to the next line
* Children must land with both feet in the red zone each time

<u>Demonstrate the task and explain the rules</u>

Scoring

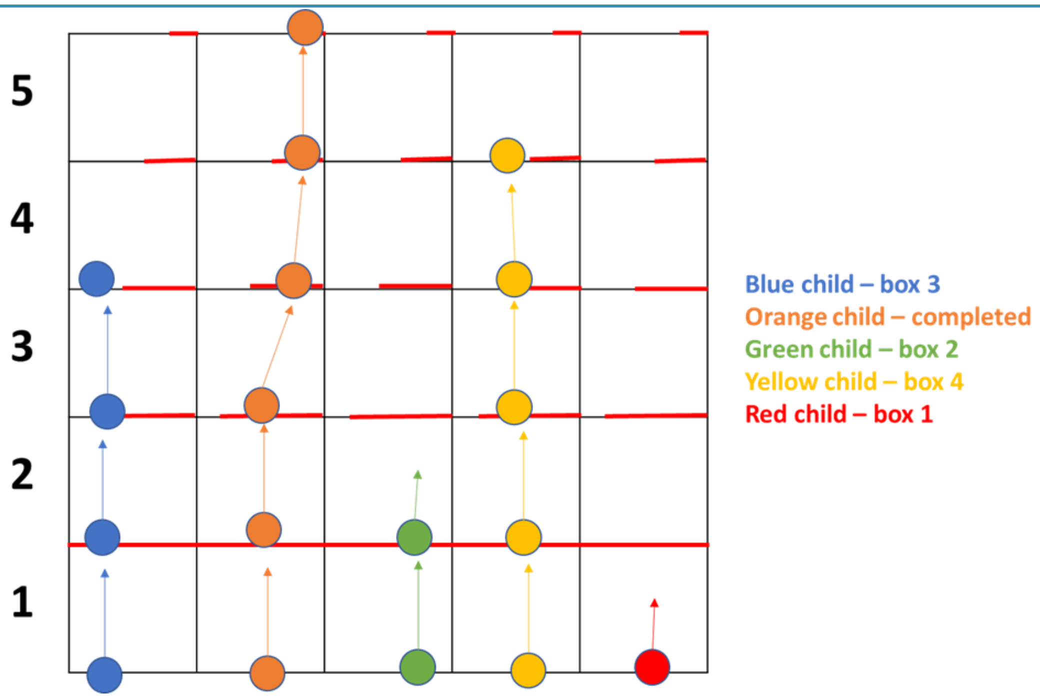
Children are scored by the **box** in which they lost **balance**.

<u>Jumping (1-6)</u>

Box on the grid where the child lost balance					

* Losing balance includes
  * Falling
  * Pausing not on the line
  * One or both of the child's feet is not in the red zone
* If the child loses balance on the line, mark that they lost balance in the box before e.g. if the child lost balance on the line between boxes 2 and 3, put a cross in box 2
* If a child completes the task, give them a score of 6

Hopping



Rules

- Children **hop on one leg** to the first line, then pause (whichever leg they want)
- Children are not allowed to hop line to line, they must use **small hops**
- When all five children reach the line, count **3 seconds**, and then set them off to the next line
- Children must not put their foot down at any point during the activity
- Children cannot change the leg on which they hop during the activity
- Children must land in the red zone on each line

<u>Demonstrate the task and explain the rules</u>

Scoring

Children are scored by the **box** in which they lost **balance.**

Hopping (1-6)

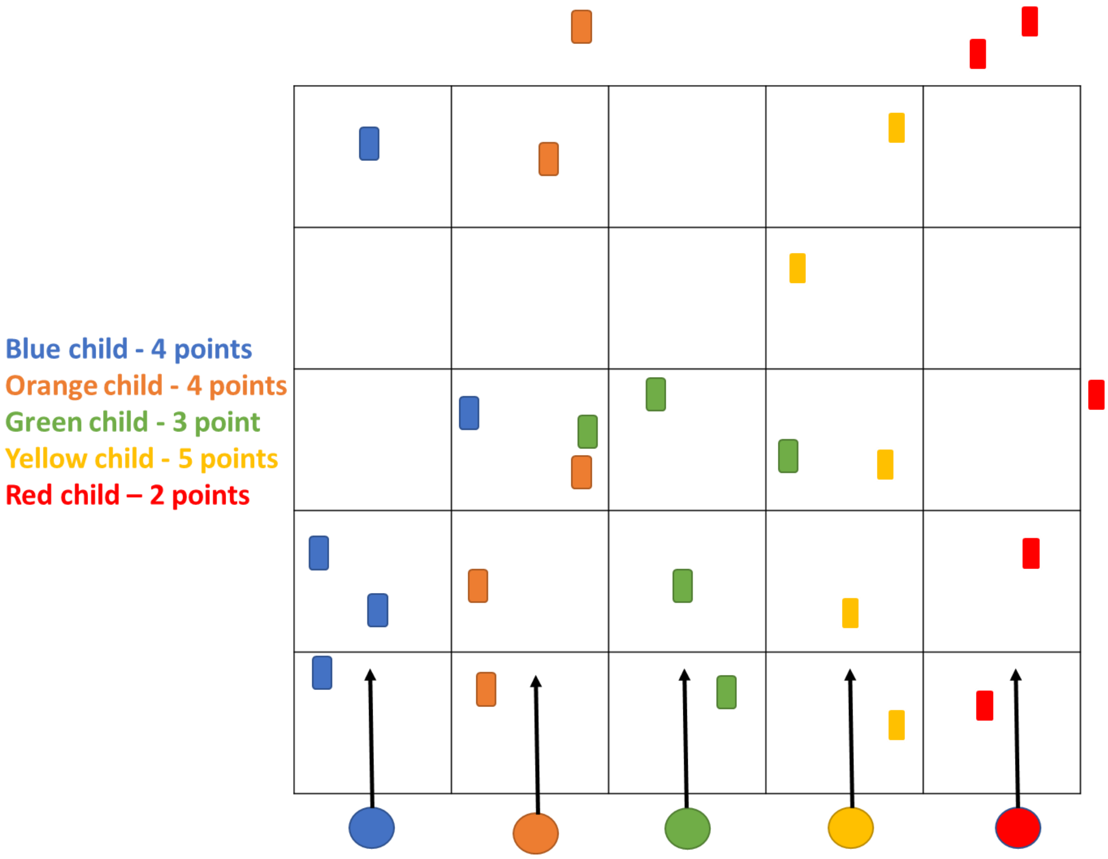
Box on the grid where the child lost balance					

- Losing balance includes
  - Falling
  - Putting their foot down
  - Pausing not on the line
  - Foot shuffling whilst pausing on the line
  - Not landing within the red zone on the line
- If the child loses balance on the line, mark that they lost balance in the box before e.g. if the child lost balance on the line between boxes 2 and 3, put a cross in box 2
- If a child completes the task, give them a score of 6

Throwing

Set up

* Each child needs 5 beanbags that are all the same colour
* Children stood next to one another on the grid should not have the same colour



beanbags

Rules

* Children aim to throw (underarm) one beanbag into each box in their lane
* Foot needs to be behind the line
* Each child can only throw one beanbag at a time
* Points are only be awarded for beanbags that land in their lane
* Only one point can be awarded per box in their lane
* Get all children to do the task right handed (all 5 beanbags), then reset the task and allow them to complete it left handed

Demonstrate the task and explain the rules

Scoring

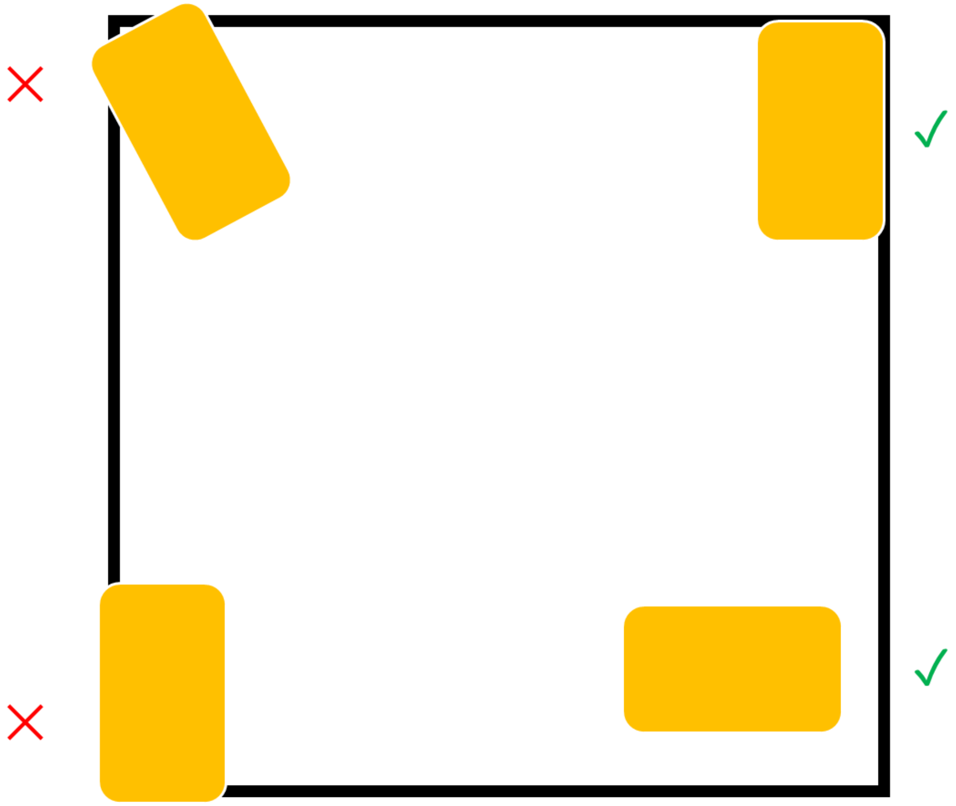
Children are scored by the number of **boxes** in their lane which are **filled** by their

Throwing

Number of Full Beanbags in the Target Zone (0-5)	L	R	L	R	L	R	L	R	L	R

beanbags.

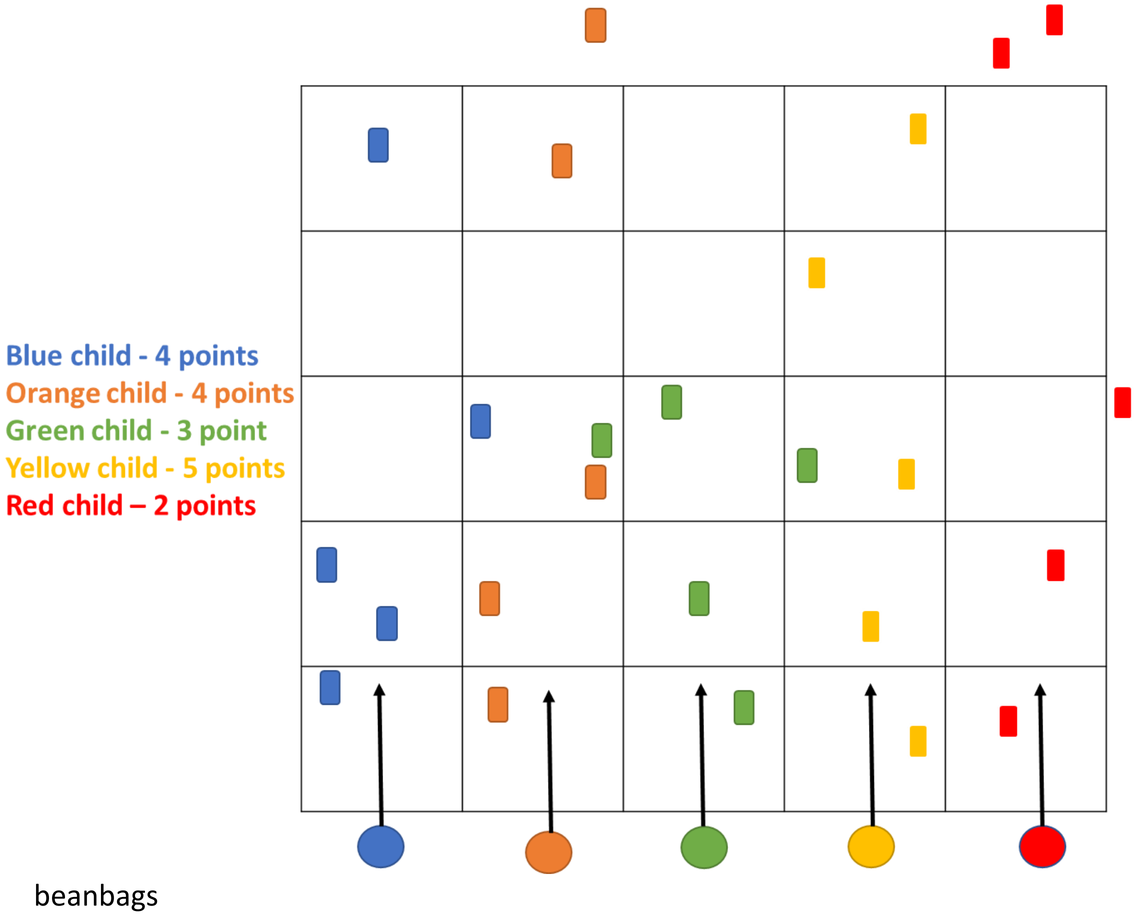
* Left handed score is noted in the L box, right handed score is noted in the R box for each child
* To get a point, the beanbag needs to be <u>fully</u> in their target box. If it is touching the boundary line but not crossing the outside edge, you can count this (see below for some examples)



Kicking

Set up

* Each child needs 5 beanbags all that are the same colour
* Children stood next to one another on the grid should not have the same colour



Rules

* Children aim to kick (along the floor) one beanbag into each box in their lane using whichever foot they want
* Children cannot change the foot they use during the activity
* Each child can only kick one beanbag at a time
* Points will only be awarded for beanbags that land in their lane
* Only one point can be awarded per box in their lane

<u>Demonstrate the task and explain the rules</u>

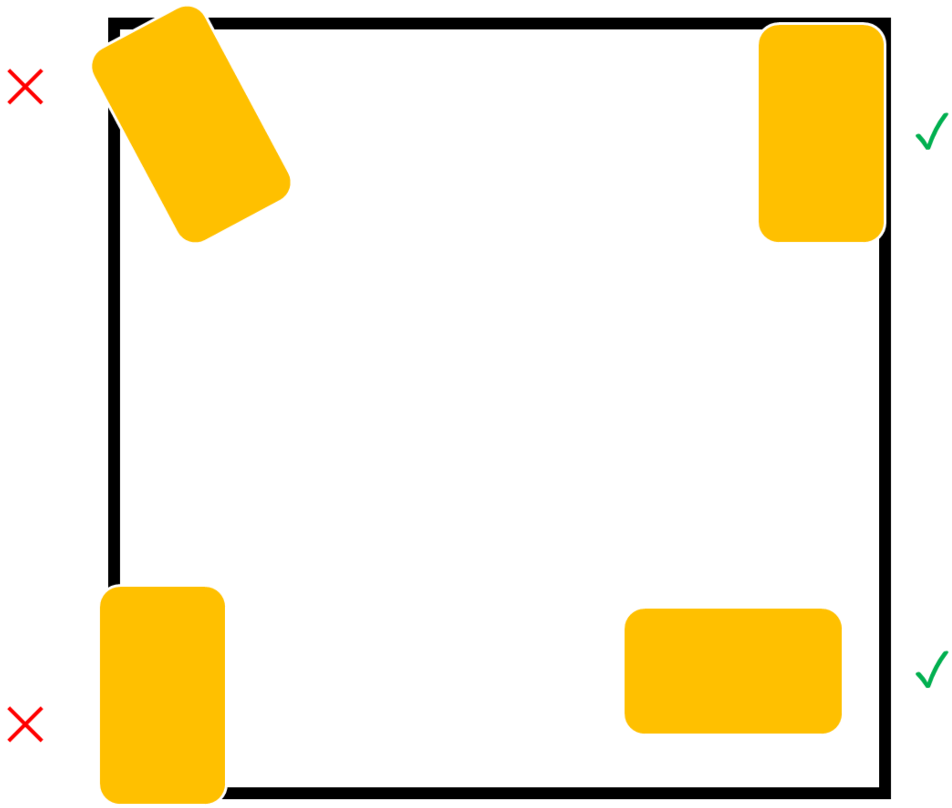
Scoring

Kicking (0-5)

Number of boxes with beanbags in					

Children are scored by the number of **boxes** in their lane which are **filled** by their beanbags.

* To get a point, the beanbag needs to be fully in their target box. If it is touching the boundary line but not crossing the outside edge, you can count this (see below for some examples)



Static Balance

Set up

- Give each child one beanbag
- Line the children up next to each other, with enough space that children can swing their arms without hitting each other

Rules

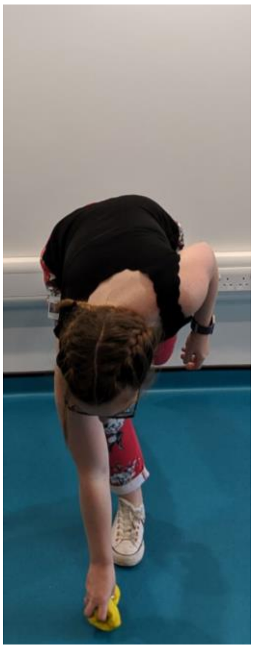
* Balances 1, 2 and 4: children pass a beanbag around their body three times whilst holding a balance




    - Balance 1 = feet together
    - Balance 2 = on one foot
    - Balance 4 = on one foot, with eyes closed

* Balance 3 - put each child's beanbag on the floor in front of them, they should attempt to pick up the beanbag in front of them whilst balancing on one leg





<u>Demonstrate each balance whilst ALL children are sat down and explain the rules, then get all groups to do balance 1 before moving onto balance 2. Count the number of rotations of the beanbags out loud.</u>

Scoring

Children are scored by whether they can successfully **complete** each **balance** (yes/no).

<u>Static Balance</u>

Legs Together	Y/ N	Y/ N	Y/ N	Y/ N	Y/ N
One Leg	Y/ N	Y/ N	Y/ N	Y/ N	Y/ N
Beanbag on the Floor One Leg	Y/ N	Y/ N	Y/ N	Y/ N	Y/ N
One Leg Eyes Closed	Y/ N	Y/ N	Y/ N	Y/ N	Y/ N

* Losing balance includes:
    - Dropping the beanbag
    - Not maintaining the balance position whilst passing the beanbag around their body
        - Wobbling is acceptable, but shuffling on their foot is not
    - Opening their eyes in an eyes closed balance
    - Putting their other hand down when picking up the beanbag in balance 4
* Place a Y (yes) or a N (no) on the response sheet to indicate whether each child successfully completed each balance

Appendix F

Teacher Response Sheet for Chapter 4

	Name 1	Name 2	Name 3	Name 4

Demographics

Gender				
Date of Birth				
Dominant Hand				
Do you think this child has motor problems?				

Running

Number of Full Lengths				
Box where the child is sat				

Jumping(1-6)

Box on the grid where the child lost balance				

Hopping (1-6)

Box on the grid where the child lost balance				

Throwing (0-5)

Number of boxes with beanbags in	L	R	L	R	L	R	L	R

Kicking (0-5)

Number of boxes with beanbags in				

Static Balance

Legs Together	Y/ N	Y/ N	Y/ N	Y/ N
One Leg	Y/ N	Y/ N	Y/ N	Y/ N
Beanbag on the Floor One Leg	Y/ N	Y/ N	Y/ N	Y/ N

448

One Leg Eyes Closed	Y/ N	Y/ N	Y/ N	Y/ N	Y/ N

Appendix G

Fidelity Checklist used in Study 1 in Chapter 4

Implementation Fidelity

Teacher ID ____

School ____

Year Group Tested ____

Running

Teacher provides clear instructions to participants for the task

Never ☐ Sometimes ☐ Always ☐

Teacher provides clear instructions to 'buddies' for the task

Never ☐ Sometimes ☐ Always ☐

Teacher demonstrates task clearly

Never ☐ Sometimes ☐ Always ☐

Buddies understand how to score the task based on demonstration

Never ☐ Sometimes ☐ Always ☐

Buddies can accurately keep count of how many full lengths participants ran

Never ☐ Sometimes ☐ Always ☐

Teacher scores task correctly (full lengths and boxes)

Never ☐ Sometimes ☐ Always ☐

Hopping

Teacher provides clear instructions to participants for the task

Never ☐ Sometimes ☐ Always ☐

Teacher provides clear instructions to 'buddies' for the task

Never ☐ Sometimes ☐ Always ☐

Teacher demonstrates task clearly

Never ☐ Sometimes ☐ Always ☐

Buddies understand how to score the task based on demonstration

Never ☐ Sometimes ☐ Always ☐

Buddies can accurately keep track of when participants fall/ put their foot down

Never ☐ Sometimes ☐ Always ☐

Teacher scores task correctly (last box)

Never ☐ Sometimes ☐ Always ☐

Comments:

Jumping

Teacher provides clear instructions to participants for the task

Never ☐ Sometimes ☐ Always ☐

Teacher provides clear instructions to 'buddies' for the task

Never ☐ Sometimes ☐ Always ☐

Teacher demonstrates task clearly

Never ☐ Sometimes ☐ Always ☐

Buddies understand how to score the task based on demonstration

Never ☐ Sometimes ☐ Always ☐

Buddies can accurately keep track of when participants lose balance/ step out

Never ☐ Sometimes ☐ Always ☐

Teacher scores task correctly (last box)

Never ☐ Sometimes ☐ Always ☐

Comments:

Walking along the line

Teacher provides clear instructions to participants for the task

Never ☐ Sometimes ☐ Always ☐

Teacher demonstrates task clearly

Never ☐ Sometimes ☐ Always ☐

Teacher scores task correctly (last marker)

Never ☐ Sometimes ☐ Always ☐

Comments:

Static Balance

Teacher provides clear instructions to participants for the task

Never ☐ Sometimes ☐ Always ☐

Teacher provides clear instructions to ‘buddies’ for the task

Never ☐ Sometimes ☐ Always ☐

Teacher demonstrates task clearly

Never ☐ Sometimes ☐ Always ☐

Buddies understand how to score the task based on demonstration

Never ☐ Sometimes ☐ Always ☐

Buddies can accurately keep track of when participants lose balance

Never ☐ Sometimes ☐ Always ☐

Teacher scores task correctly (last box)

Never ☐ Sometimes ☐ Always ☐

Comments:

Kicking

Teacher provides clear instructions to participants for the task

Never ☐ Sometimes ☐ Always ☐

Teacher provides clear instructions to 'buddies' for the task

Never ☐ Sometimes ☐ Always ☐

Teacher demonstrates task clearly

Never ☐ Sometimes ☐ Always ☐

Buddies understand how to score the task based on demonstration

Never ☐ Sometimes ☐ Always ☐

Buddies can accurately keep count of how many beanbags in the target area

Never ☐ Sometimes ☐ Always ☐

Teacher scores task correctly (how many full beanbags in target area)

Never ☐ Sometimes ☐ Always ☐

Comments:

___

___

___

___

Throwing

Teacher provides clear instructions to participants for the task

Never ☐ Sometimes ☐ Always ☐

Teacher provides clear instructions to ‘buddies’ for the task

Never ☐ Sometimes ☐ Always ☐

Teacher demonstrates task clearly

Never ☐ Sometimes ☐ Always ☐

Buddies understand how to score the task based on demonstration

Never ☐ Sometimes ☐ Always ☐

Buddies can accurately keep count of how many beanbags in the target area

Never ☐ Sometimes ☐ Always ☐

Teacher scores task correctly (how many full beanbags in target area)

Never ☐ Sometimes ☐ Always ☐

Comments:

Appendix H

Implementation Fidelity Checklist for Studies 2 & 3 in Chapter 4

Implementation Fidelity Checklist

Teacher ID:___
____

School: ______
____

Class Tested:
____

Preparation

Essential:	Preferable:
☐ Grid is set up	☐ Teams are located in the lane on the grid they refer to on the teachers sheet
☐ Teacher has a stop watch/ timer	☐ Physically show each team their lane
☐ Teacher has pens	Explain that the row they are sat in is their team
☐ Teacher lines students up in their teams	Explain that each activity can earn their team points
☐ Within each team, children are in the order they appear on the teacher's sheet	Explain how to keep note of team scores on the score sheet
	☐ Explain that they will receive no points if they do not follow the rules

Comments:

Running

Essential:

- ☐ Explain that they will be running for 15 seconds
- ☐ Explain that they run from the start line to the back line as many times as possible
- ☐ Explain that they should run as quickly as they can
- ☐ Explain that they must touch the line with their foot at both sides
- ☐ Explain when they say stop, the children must sit down as quickly as possible
- ☐ Accurate demonstration of the task
- ☐ Teacher shouts stop after 15 seconds of running (time once to check)
- ☐ Scores full lengths correctly (best judgement)

Preferable:

- ☐ The first person to sit down when they say stop wins a bonus point
- ☐ Clarify with class for understanding of rules
- ☐ Ensure the children not running from each team are out of the way
- ☐ Teacher keeps a tally for each child whilst running
- ☐ Teacher uses a timer which beeps after 15 seconds
- ☐ Explain that they will get no points if they don't run all the way to the lines
- ☐ Explain that they must stay in their own lane when running

Comments:

____

____

____

____

____

Jumping

Essential:

Preferable:

- ☐ Explain that they must do small jumps from the first line to the second line and pause until they say go
- ☐ Explain that they will do the same from the second line to the third line etc.
- ☐ Explain that on each line they must land with both feet in the red/ coloured zone
- ☐ Accurate demonstration
- ☐ Pauses children for approximately 3 seconds on each line
- ☐ Scores children correctly (best judgement)
- ☐ Ensure all children are sat down when explaining the activity
- ☐ Explain that they will get no points if they don't follow the rules
- ☐ Explain that it isn't a race, they are scored on how well they can jump
- ☐ Explain that they should only start jumping when they say go
- ☐ Actively times 3 seconds
- ☐ Keeps all children sat down until their turn so they don't get to practice beforehand
- ☐ Explain that they cannot just jump from line to line
- ☐ Explain that they must pause on the back line too

Comments:

____

____

____

____

____

Hopping

Essential:

- ☐ Explain that they must do small hops from the first line to the second line and pause until they say go
- ☐ Explain that they will do the same from the second line to the third line etc.
- ☐ Explain that they can hop on any leg but must not change legs during activity
- ☐ Explain that they cannot just hop from line to line
- ☐ Explain that on each line they must land on one foot in the red/ coloured zone
- ☐ Accurate demonstration
- ☐ Pauses children for 3 seconds on each line
- ☐ Scores children correctly (best judgement)

Preferable:

- ☐ Ensure all children are sat down when explaining the activity
- ☐ Explain that they will get no points if they don't follow the rules
- ☐
- ☐ Explain that it isn't a race, they are scored on how well they can hop
- ☐ Actively times 3 seconds
- ☐ Keeps all children sat down until their turn so they don't get to practice beforehand
- Explain that they must pause on the back line too
- ☐ Explain that when they say they should put one leg in the air, and only start hopping when they say go

Comments:

____

____

____

____

____

Throwing

Essential:

- ☐ Explain that they should aim to throw one beanbag into each box in their lane
- ☐ Explain that they should throw underarm
- ☐ Explain that their foot should be behind the line when throwing
- ☐ Explain that they get one point for each box they fill in their lane
- ☐ Explain that they will do the activity twice, once throwing all five beanbags with their right hand, once with their left
- ☐ Accurate demonstration
- ☐ Ensures children are throwing with the correct hand and re-sets if not
- ☐ Ensures children throw underarm and re-sets if not
- ☐ Physically checks beanbags which land near a line
- ☐ Scores children correctly (best judgement)

Preferable:

- ☐ Ensure all children are sat down when explaining the activity
- ☐ Explain that they will get no points if they don't follow the rules
- ☐ Explain that they do not get more points for further away boxes
- ☐ Before each child starts, asks them to hold one beanbag in their right/left hand in the air to check they understand

Comments:

____

____

____

Kicking

Essential:

- ☐ Explain that they should aim to kick one beanbag into each box in their lane
- ☐ Explain that they should kick the beanbag along the floor, not out of hands
- ☐ Explain that the beanbags should be behind the line before kicking
- ☐ Explain that they can use whichever leg they like to kick, but must not change leg
- ☐ Accurate demonstration
- ☐ Ensures children are kicking along the floor and re-sets if not
- ☐ Physically checks beanbags which land near a line
- ☐ Scores children correctly (best judgement)

Preferable:

- ☐ Ensure all children are sat down when explaining the activity
- ☐ Explain that they will get no points if they don't follow the rules
- ☐ Explain that they do not get more points for further away boxes
- Explain that they get one point for each box they fill in their lane

Comments:

____

____

____

____

____

Balance

Essential:

- ☐ Explains there will be a series of balance poses they need to hold
- ☐ Balance 1: feet need to be kept together at all times
- ☐ Balance 1: standing up straight you must pass the beanbag around your body with my count
- ☐ Explain with my count: when I say 1, you pass it around your body the first time, 2 the second time etc.
- ☐ Ensures all children are sat down until it is their turn so they get no chance to practice
- ☐ Balance 2: explains that they should do the same again but on one leg
- ☐ Balance 3: explains that they should place the beanbag in front of them
- ☐ Balance 3: explains that they should try to retrieve the beanbag, standing on one leg using one hand
- ☐ Balance 4: explains that they should stand on one leg and close their eyes to pass the beanbag around their body
- ☐ Accurate Demonstration for each balance

Preferable:

- ☐ Ensure all children are sat down when explaining the activity
- ☐ Explain that they will get no points if they don't follow the rules
- ☐ Removes beanbags from throwing and kicking tasks and hands each child a beanbag only when it is their turn
- ☐ Explain that they can pass the beanbag around their body either way
- ☐ Explain they should only pick up the beanbag when the teacher says so
- ☐ Explain that they should only start passing the beanbag around their body when the teacher starts counting
- ☐ Explain that after the 3rd rotation they should drop the beanbag in front of them, but maintain the balance until their beanbag hits the floor
- ☐ Balance 4: explains they will get no points if they open their eyes

- ☐ Scores children correctly (best judgement)

Comments:

Appendix I

Recruitment flyer for Chapter 5, work package 1

BORNINBRADFORD For a Healthy Future

School-Based Assessment of Fundamental Movement Skills
FUNMOVES

What is Born in Bradford (BiB)?
Born in Bradford is one of the largest research studies in the UK, which follows the lives of over 30,000 people in Bradford to find out what influences their health and wellbeing.

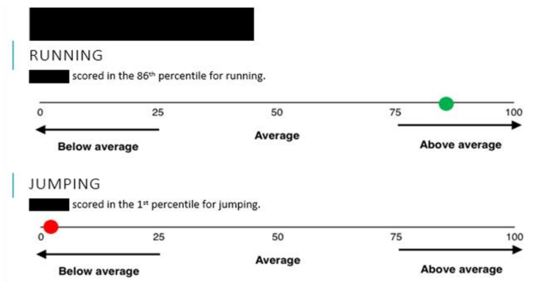
What are Fundamental Movement Skills (FMS)?
FMS are a group of motor skills which are important for participation in physical activity (e.g. running, jumping, throwing and balancing).

Why is it important to assess FMS?
Research has found that FMS have an impact upon health (both physical and mental) as well as academic performance.

What is FUNMOVES?
FUNMOVES is an evidence-based assessment of childhood FMS, which is led by teachers, and has been modified based on feedback from schools. It takes approximately 2 hours to test one class, which can be spread out across a number of P.E. lessons.

What will this involve for my school?

- A one hour training session with teachers and teaching assistants
- Years 1-6 completing FUNMOVES
- A second member of staff present during testing to help each class teacher
- A researcher observing testing
- A one hour focus group with teachers after testing
- And either:
    - One class completing the assessment twice, a few weeks apart
    - Five children from each year group completing a researcher-led assessment of FMS



What information will my school receive after testing?
You will receive reports for each child detailing their performance on each of the 6 activities compared to the rest of their year group. This may help you to identify children that need additional support.

When is it?
We are looking to recruit schools to test FUNMOVES between April and July 2020

How do I sign up?
If you are interested in taking part, please contact Lucy (ps13lhe@leeds.ac.uk) for more information.

UNIVERSITY OF LEEDS