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The Effectiveness of School-Based Interventions on the Fundamental Movement Skill Proficiency Among a Cohort of Irish Primary School Children

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PhD

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Abstract

THE EFFECTIVENESS OF SCHOOL-BASED INTERVENTIONS ON THE FUNDAMENTAL MOVEMENT SKILL PROFICIENCY AMONG A COHORT OF IRISH PRIMARY SCHOOL CHILDREN

Lisa Bolger

Background: Fundamental movement skills (FMS) are basic observable patterns of movement such as running and jumping. FMS facilitate participation in physical activity and sport. The ability to perform FMS correctly (i.e. FMS proficiency) is associated with numerous health benefits and is important for the holistic development of children. FMS proficiency among primary school children worldwide is low. Thus, interventions aimed at improving FMS levels among children are warranted. Therefore, this thesis aimed to assess the FMS proficiency among a cohort of Irish primary school children and examine the effectiveness of a physical activity (PA) (Year 1) and a multicomponent FMS (Year 2) intervention on children's FMS levels. **Methods:** FMS proficiency was assessed using the Test of Gross Motor Development-2 (TGMD-2), across academic year 2014/2015 (Year 1) and academic year 2015/2016 (Year 2). Participants were children from three primary schools (two intervention, one control) in south Ireland. In Year 1 (N=187), intervention (n=96) and control (n=91) groups were children from senior infant and fourth classes. In Year 2 (N=357), intervention (n=195) and control (n=162) groups were senior infant, 1st, 4th and 5th class children. At baseline Year 1, an analysis of variance (ANOVA) was used to assess age and sex related differences in FMS proficiency among all participating children (N=203). Following both the PA- and FMS-intervention, repeated measures ANOVAs were conducted to investigate the effectiveness of each intervention. Only participants with complete data sets at baseline and post-intervention testing were included in the analyses. **Results:** FMS levels among Irish primary school children are similar to children worldwide, with age and sex differences evident. Older children scored significantly higher than younger children in both locomotor ($p<.05$) and object-control scores ($p<.05$). Boys scored significantly higher than girls in object-control score ($p<.05$), while girls scored significantly higher in locomotor score ($p<.05$). Repeated measures ANOVAs, revealed that following the PA-intervention (Year 1), the intervention group significantly improved locomotor proficiency ($p<.05$; *ES*: .220), with no changes in object-control or overall proficiency. No group-time interactions were found. Following Year 2, the intervention group significantly improved locomotor, object-control and overall proficiency ($p<.0001$; *ES*: .187-.325). Group-time interaction effects were found for subsets and overall FMS, in favour of the intervention group ($p < .001$; *ES*: .262-.402). **Conclusion:** FMS levels among primary school children in Ireland, and worldwide, are less than satisfactory. While a PA-based intervention improved locomotor proficiency, it was not more effective at improving children's FMS levels than the Irish PE curriculum only. However, a multicomponent FMS-based intervention significantly improved locomotor, object-control and overall FMS proficiency among primary school children (large effect sizes for all). It is suggested that multicomponent FMS-based interventions should be implemented across primary schools in Ireland to improve FMS proficiency level, as greater proficiency is related to greater PA participation and numerous health benefits.

Declaration

The substance of this thesis is the original work of the author and due reference and acknowledgement has been made, where necessary, to the work of others. No part of this thesis has already been submitted for any degree and is not being concurrently submitted in candidature for any degree.

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Table of Contents

PART I: Thesis

Part II: Appendices incorporating publications to date

Appendix A: Publications

List of Tables

List of Figures

Chapter 1:

Introduction

1.1 Introduction

Fundamental movement skills (FMS) are basic observable movement patterns such as running, jumping and catching (Gallahue & Ozmun, 2006). They are the foundation upon which more complex sport-specific skills are based (Gallahue & Ozmun, 2006), henceforth being commonly referred to as 'building blocks' in this context. For example, the overarm throw forms the basis of the technique for the tennis serve, badminton overhead clear and javelin throw among others (Thomas & French, 1985; Wickstrom, 1983).

The acquisition of FMS facilitate, and are beneficial for, participation in physical activity (PA) and sport among childhood, adolescence and adulthood (Clark & Metcalfe, 2002; Gallahue & Ozmun, 2006; Logan, Robinson, Wilson, & Lucas, 2011). FMS are usually divided into three categories: (i) locomotor, (ii) object-control and (iii) stability skills. Locomotor skills involve the movement of the body from one location to another and include skills such as running, jumping and hopping. Object-control skills involve the manipulation of an object and include throwing, catching and kicking. Stability skills are those which enable the body to maintain balance and equilibrium, either statically or dynamically, and include balancing, twisting and dodging (Lubans, Morgan, Cliff, Barnett, & Okely, 2010).

According to the hourglass model for motor skill development (Figure 1.1, adapted from Gallahue and Ozmun (2006)), children have the potential to master FMS (i.e. proficiently perform) by the age of seven (Gallahue & Ozmun, 2006). However, these skills are not acquired naturally (Barnett, Stodden et al., 2016; J. E. Clark, 2005; Pang & Fong, 2009). Rather, they must be learned and practiced (Pang & Fong, 2009) through quality instruction, practice opportunities and feedback (Gallahue, Ozmun, & Goodway, 2012; Pang & Fong, 2009; Payne & Isaacs, 2002). Therefore, the early years of life (± 3-7 years) are a critical period in the development of FMS (Gallahue et al., 2012).

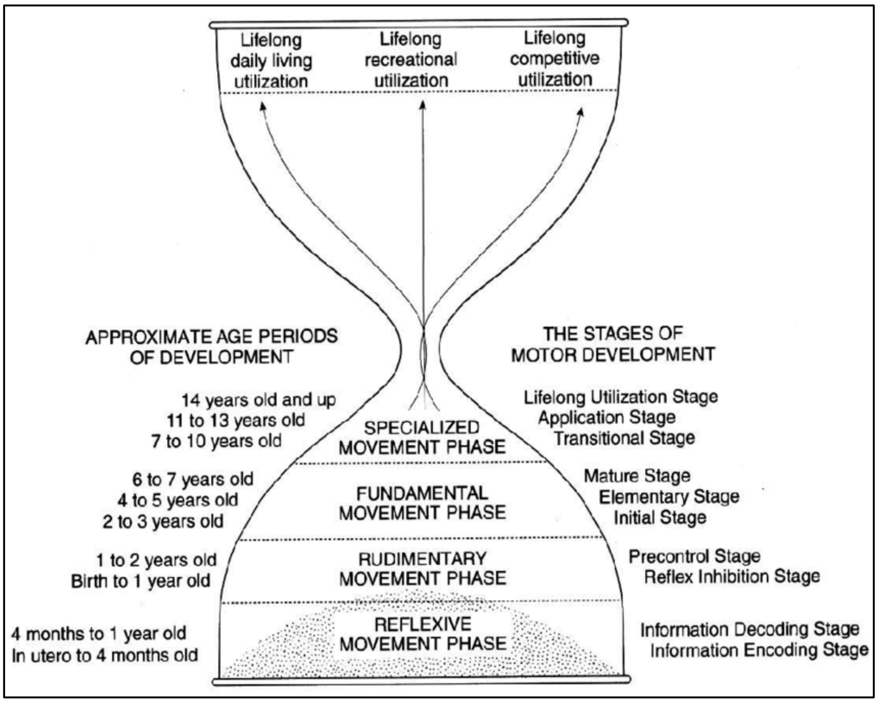

Figure 1.1: Gallahue and Ozmun's (2006) hourglass model of motor development

The ability to perform FMS correctly (i.e. FMS proficiency) is associated with numerous health benefits and is integral to physical, psychological and social development as well as the overall well-being of children (Barnett, Stodden et al., 2016). FMS proficiency among children has been found to be positively associated with higher levels of PA (Holfelder & Schott, 2014), physical fitness (Barnett, Stodden et al., 2016; Cattuzzo et al., 2016), as well as cognitive functioning and academic performance (Haapala, 2013). It is also associated with a healthier weight status (Barnett, Stodden et al., 2016; Lubans et al., 2010). Furthermore, longitudinal evidence indicates that FMS proficiency tracks through childhood (Branta, Haubenstricker, & Seefeldt, 1984; Malina, 1990), into adolescence (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; McKenzie et al., 2002) and is a significant predictor of PA during this period of adolescence (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009).

In recent times, childhood obesity has become a global health concern (World Health Organization [WHO], 2018a). It is a cause of both short- and long-term adverse health effects, not limited to physical (e.g. high blood pressure, high cholesterol, metabolic syndrome, type 2 diabetes), but also psychological, social and behavioural issues including self-esteem, depression, body image and reduced quality of life. Worldwide figures have recently revealed that the prevalence of childhood overweight/obesity levels have dramatically increased from 4% in 1975 to over 18% (340 million) in 2016 among children and adolescents (World Health Organization [WHO], 2018b). A contributing factor to childhood obesity, physical inactivity, has also been highlighted as a major public health challenge worldwide (World Health Organization [WHO], 2018c). Despite the significant health benefits of regular physical activity (including improved muscular and cardiorespiratory fitness, bone health as well as aiding the prevention of many non-communicable diseases (NCDs)), physical inactivity has been identified as the fourth leading risk factor for global mortality (World Health Organization [WHO], 2018d). In light of these global health concerns and based on the existent reciprocal relationship between FMS and PA (Stodden et al., 2008), the area of motor skill development among this cohort has gained significant interest internationally as a potential mechanism to combat these global problems.

Research assessing FMS proficiency among primary school aged children (age range: 4-13 years) has reported less than desired levels (Bardid et al., 2016; Bellows, Davies, Anderson, & Kennedy, 2013; Bolger et al., 2017; Bryant, Duncan, & Birch, 2014; Khodaverdi, & Bahram, 2015; Kordi, Nourian, Ghayour, Kordi, & Younesian, 2012; Mitchell et al., 2013; O'Brien, Belton, & Isaartel, 2016; Spessato, Gabbard, Valentini, & Rudisill, 2013). Recent studies suggest that children demonstrate lower proficiency in performing these movement skills in comparison with preceding generations (Bardid et al., 2016; Bardid, Rudd, Matthieu, Polman, & Barnett, 2015; Spessato, Gabbard, Valentini et al., 2013). There is a currently a dearth of literature examining the FMS levels among Irish primary school children. Furthermore, there is an absence of research that has (i) collated the levels of FMS proficiency across countries worldwide or (ii) provided an overview of the worldwide proficiency among primary school aged children.

With the early years identified as critical period for FMS development, interventions aimed at improving FMS are warranted worldwide among primary school aged children. To date, little research has evaluated the effectiveness of PA-based interventions (which do not have a specific FMS focus) at improving fundamental movement skill proficiency.

However, more specifically, motor skill interventions have been reported to positively improve FMS competence (both locomotor and object-control) among primary school aged children (Morgan et al., 2013). It has been found that motor skill interventions most consistently associated with improvements in FMS are those that include a multi-disciplinary approach, maintain progress over a long duration (> 6 months), provide multiple sessions per week, are delivered by a PE specialist and incorporate parental involvement (e.g. 'at home' practice assisted or supervised by parents, parent evenings) (Tompsett, Sanders, Taylor, & Cobley, 2017). In Ireland, no interventions, either PA-based or FMS-based, aimed at improving proficiency across a broad range of FMS among children, have been reported or evaluated.

At present in Ireland, childhood physical inactivity and obesity among primary school children are of major health concerns (Kelly, Gavin, Molcho, & Nic Gabhainn, 2012; Tremblay, 2014; Woods, Moyna, Quinlan, Tannehill, & Walsh, 2010). International comparisons reveal that Irish children have low PA levels as well as high levels of sedentary behaviour (Tremblay, 2014), with only 19% of primary school aged children reaching the recommended 60 minutes of MVPA daily (Woods et al., 2010). It has also been reported that Irish primary school children receive only 46 minutes PE per week (European Commission/EACEA/Eurydice, 2013), the lowest of all EU countries. Furthermore, childhood obesity figures from Ireland revealed one in four children are classified as overweight/obese, with Ireland predicted to be the fattest of 53 European nations by 2030 (Webber et al., 2014). Based on the positive association between FMS and PA and the inverse association with weight status (Cattuzzo et al., 2016; Lubans et al., 2010), the evaluation of (i) the current FMS levels among Irish primary school children, and (ii) the effectiveness of interventions aimed at improving FMS are warranted. The findings may reveal that the implementation of effective interventions have the potential be one such avenue to help combat these national (and global) health problems.

1.2 Aims and Hypotheses

The aims and hypotheses of the research were as follows:

1. To systematically review the levels of FMS proficiency worldwide among primary school aged children (4-13 years), assessed using the Test of Gross Motor Development – 2 (TGMD-2) (Ulrich, 2000)

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2. To investigate age and sex differences in FMS proficiency among a cohort of Irish primary school children

HØ1: There will be no significant age and/or sex- related differences in FMS proficiency among a cohort of Irish primary school children
HA1: There will be a significant age and/or sex- related differences in FMS proficiency among a cohort of Irish primary school children

(Based on previous literature, it is hypothesised that older children will demonstrate greater FMS proficiency than the younger cohort and that boys will have greater object-control proficiency than girls)

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3. To compare the FMS proficiency levels of a cohort of Irish primary school children to the normative data of the TGMD-2 and to other countries worldwide

HØ2: There will be no significant difference between the FMS proficiency levels of a cohort of Irish primary school children and TGMD-2 normative data and other countries worldwide
HA2: There will be a significant difference between the FMS proficiency levels of a cohort of Irish primary school children and TGMD-2 normative data and other countries worldwide

(Based on previous literature, it is hypothesised that Irish primary school children will demonstrate similarly low levels to those reported among children worldwide in recent literature, irrespective of cultural and sporting habits)

4. To examine the accuracy of children's perceptions of their FMS proficiency and investigate the association between perceived movement skill competence and PA among a cohort of Irish primary school children

HØ3: There will be no significant difference between children's perceived and actual movement skill competence and there will be no association perceived movement skill competence and PA levels among a cohort of Irish primary school children

HA3: There will be a significant difference between children's perceived and actual movement skill competence and there will be no association perceived movement skill competence and PA levels among a cohort of Irish primary school children

(Based on previous literature, it is hypothesised that children will overestimate their actual FMS competence. It is also hypothesised that there will be a significant relationship between children's perceived movement skill competence and their PA level.

5. To design and implement a physical activity-based intervention in two Irish primary schools across an academic school year and evaluate its effectiveness on children's FMS proficiency

HØ4: There will be no significant difference in children's FMS proficiency following a physical activity intervention delivered across one academic year

HA4: There will be a significant difference in children's FMS proficiency following a physical activity intervention delivered across one academic year

(Based on previous literature, it is hypothesised that there will be no significant improvement in children's FMS proficiency following the PA intervention)

6. To design and implement an age-appropriate multicomponent FMS-based intervention to children in two Irish primary schools across an academic year, and evaluate its effectiveness on children's FMS proficiency

HØ5: There will be no significant difference in children's FMS proficiency following a 26-week multicomponent FMS-based intervention
HA5: There will be a significant difference in children's FMS proficiency following a 26-week multicomponent FMS-based intervention

(Based on previous literature, it is hypothesised that there will be a significant improvement in children's FMS proficiency following the PA intervention)

1.3 Significance of the Research

In response to the rise in sedentary behaviour and associated global obesity epidemic among children (Kohl et al., 2012; WHO, 2018a, 2018c), motor skill proficiency among children has received greater attention as a possible mechanism to combat these global problems. However, as of yet, no review has collated the FMS proficiency levels of children across many countries worldwide, thus providing a global overview of the current FMS status of children. The systematic review conducted as part of the current research study included studies that assessed FMS using the TGMD-2, a commonly used measurement tool that has been shown to be valid and reliable among children (Ulrich, 2000). The collation of studies examining FMS proficiency levels among primary school aged children will serve as reference data for future international studies, enabling researchers to compare levels with those reported previously with relative ease. Furthermore, the analysis conducted as part of this systematic review will provide an overall indication of FMS levels of children at each individual age during the primary school years (from 4-13 years) as well as across early childhood (4-8 years) (Woodward-Lopez, Ritchie, Gerstein, & Crawford, 2006) and middle to late childhood (8-13 years) (A.

V. Clark, 2005) years. These findings will serve as a global reference and comparative data for all studies conducted among primary school age children using the TGMD-2.

In Ireland, a physical inactivity and obesity crisis currently exists among children (Woods et al., 2010), concerns of which have been recognised globally (Tremblay, 2014; Webber et al., 2014). International comparisons reveal that PA levels among Irish children are low, while levels of sedentary behaviour are high (Tremblay, 2014), with only 19% of primary school aged children reaching the recommended 60 minutes of MVPA daily (Woods et al., 2010). Notably, Irish children also receive less PE time than all other EU countries (European Commission/EACEA/Eurydice, 2013). Furthermore, with one in four Irish children classified as overweight or obese, Ireland has been predicted, by the WHO, to be the fattest of 53 nations by 2030 (Webber et al., 2014). Based on the existent reciprocal relationship between FMS and PA (Stodden et al., 2008) and the associated health benefits (physical, psychological and social) (Barnett, Stodden et al., 2016), the evaluation of the FMS proficiency of Irish primary school children may prove invaluable. In Ireland, there is a dearth of research examining the FMS levels among primary school aged children. Recently, one study has been conducted by Farmer, Belton, and O'Brien (2017) assessing the FMS proficiency levels of 8-12 year old primary school girls (n=160; mean age: 10.7) revealing low FMS levels among this cohort, with only 2% of the sample demonstrating mastery across all seven skills tested. One other study, conducted by Breslin, Murphy, McKee, Delaney, and Dempster (2012), included the assessment of the FMS levels among a cohort of children of primary school age in Northern Ireland. However, the scoring protocol of the tool used was not described nor were the current levels among the cohort reported. Recent studies have been conducted among an Irish adolescent population (Lester et al., 2017; O'Brien et al., 2016), indicating that Irish primary school children enter adolescence with low FMS proficiency. Therefore, this novel research will serve to establish the FMS proficiency levels among a cohort of Irish primary school children while also providing an insight into any age and/or sex differences in FMS levels within this cohort. The FMS levels found among Irish primary school children will provide comparative data with international studies with similar age- and sex-related cohorts and with future studies conducted among Irish children. It will also serve as reference data for future research exploring longitudinal trends in FMS among Irish primary school children. Knowledge of the FMS levels of Irish primary school children will aid and assist the development of appropriate interventions aimed at improving movement skill proficiency.

There has been limited research conducted worldwide, with no published research conducted in Europe, that examines the relationships between (i) perceived and actual competence and (ii) perceived competence and PA among children, using aligned measurement tools. The research reviewed in this section suggests that inflated perceptions of competence may positively influence PA participation among children in activities that improve actual FMS. Therefore, an understanding of these relationships will prove invaluable in the development of motor skill interventions to increase actual FMS, PA levels and the overall health and well-being of children.

International evidence has revealed the potential of motor skill interventions to improve children's FMS proficiency. However, In Ireland, there has been no published research evaluating the effectiveness of such interventions on children's movement skills. Therefore, the design, implementation and evaluation of two primary school-based interventions may identify effective strategies to improve FMS proficiency levels among Irish primary school children. Thus, this research may aid teacher training colleges (and existing teachers), national coaching and government bodies in the development of policies and strategies to improve FMS and PA levels as well as the overall health and well-being of children. The identification of an effectiveness intervention to improve FMS among children may prove significant from an individual, local and national perspective; improving overall health among children and reducing the current and future economic burden of both physical inactivity and obesity.

1.4 Project Spraoi

The current research was conducted as part of a larger research study, 'Project Spraoi'. *Project Spraoi* is a primary school-based health promotion intervention in Ireland, designed and developed to positively influence children's physical activity levels and nutritional habits, thereby improving the overall health of Irish school children (Coppinger, Lacey, O'Neill, & Burns, 2016).

Project Spraoi is based on 'Project Energize', a physical activity and nutrition programme delivered through primary schools in New Zealand (Graham et al., 2008), and has been suitably adapted for cultural, economic and educational differences between the two countries (Coppinger et al., 2016). Project Energize was first implemented across 124 primary schools from 2004 to 2006 as a longitudinal randomised controlled trial, with the effectiveness of the Project Energize intervention evaluated among the 5- to 7-year old and 10- to 12-year-old cohorts. Findings revealed a reduction in the accumulation of body fat among the younger cohort as well as a reduced rise in systolic blood pressure among the older children the intervention schools, in comparison to the control schools. In 2011, by which time 233 schools were engaged in Project Energize, an evaluation of body size (using BMI) and physical fitness (assessed using a 550m run test) was conducted in which data from 2474 younger (6- to 8-year-old) and 2330 older (10- to 12-year-old) children were collected. It was found that the prevalence of overweight/obesity among both the younger and older 'Energized' children was 31% and 15% lower in comparison to the cohort of 'unEnergized' children from the randomised control trial in 2004-2006. Physical fitness was also found to be significantly higher among both the younger (14%) and older (11%) cohorts in comparison to an age-matched cohort of children from a different region. Since 2011, Project Energize has further developed and is currently implemented in all 242 primary schools in the Waikato area as well as 70 schools from other areas, reaching 53,000 children (Rush et al., 2016). Project Energize has been shown to be a sustainable project (in existence >10 years), effective in reducing obesity and increasing physical fitness among school children while remaining cost effective ($45/child/year or €27/child/year) and efficient (Rush et al., 2016). In contrast to *Project Spraoi*, which is primarily research-based with no external funding support, Project Energize is funded by the Waikato District Health Board of New Zealand. Collaboration and support between *Project Spraoi* and Project Energize is on-going, which includes the sharing of resources and ideas.

The aim of *Project Spraoi* is to implement and evaluate the effectiveness of school-based interventions among Irish primary school children. *Project Spraoi* was first implemented in Ireland in the academic year 2013/2014 (Year 1) in four primary schools in Cork, with a further two schools assigned as control schools. In the academic year 2014/2015 (Year 2), the intervention was delivered in a further four primary schools, with an additional control school also recruited, all from the Cork City and County area.

Central to each of the *Project Spraoi* interventions (and to Project Energize) is the 'Energizer' (Coppinger et al., 2016). Each intervention school was assigned an Energizer (who was a postgraduate researcher, qualified in the area of physical activity and/or nutrition), who delivered the intervention. Energizers acted as 'agents of change' in the school, as opposed to additional members of staff. The roles and responsibilities of the Energizer included:

- conducting a needs analysis with the school principal, teachers and staff
- designing a tailored action plan and intervention for the school based on the needs analysis
- modelling physical activity (known as 'huff and puff') and nutrition-based lessons
- providing resources including games manuals, equipment, useful online links for game/ activity ideas
- organising continuous professional development workshops (e.g. PA, FMS, gymnastics)
- creating and organising whole-school physical activity initiatives and competitions (e.g. pedometer challenge)
- providing useful information and resources to children and families through distribution in the school (e.g. information sheets on PA and healthy eating, healthy eating fridge magnets)
- promoting physical activity and healthy nutritional habits throughout the school community
- providing on-going support and assistance to classroom teachers in any way possible

An integral element of *Project Spraoi*, encouraged by the Energizer, was the promotion of 20 minutes *huff and puff* (moderate-to-vigorous physical activity) activities each school day. Moderate-to-vigorous physical activity (MVPA) is activity requiring a moderate amount of effort, which increases heart and breathing rate, equating to 3-6 metabolic equivalents or METs (units used to express activity intensity, in which sitting quietly equates to one MET) (World Health Organization [WHO], 2018e). Examples of MVPA include running, circuits, dance, skipping, tag-games and continuous relays. MVPA has numerous associated health benefits including improved function of the cardiorespiratory system and fitness, muscular and bone strength, mood, concentration, cognitive functioning and academic performance. Children who are regularly active have been shown to be less likely to become overweight/obese, have lower blood pressure and cholesterol levels and have decreased risk of developing various diseases including type 2 diabetes (Janssen, & LeBlanc, 2010).

Recommendations by the World Health Organization (World Health Organization [WHO], 2018f) and outlined in the National Guidelines on Physical Activity for Ireland (Department of Health and Children, Health Service Executive, 2009) require children to engage in a minimum of 60 minutes of MVPA daily, which may be accumulated throughout the day. As children spend approximately one third of their waking day at school, it would seem logical to accumulate 20 minutes MVPA (one third of that recommended) throughout the school day. Thus, *Project Spraoi* encourages teachers to facilitate 20 minutes of MVPA each day, which may be accumulated in a single PA/Physical Education (PE) session or through numerous activity breaks throughout the school day e.g. two x 10 minutes, four x 5 minutes.

Another key element of *Project Spraoi* is the promotion of healthy nutritional habits including the encouragement for children to select water and milk as everyday drinks, increase fruit and vegetable consumption as well as to reduce the intake of sugary drinks and energy-dense low-nutrient foods (Coppinger et al., 2016). Nutritional workshops as well as healthy eating promotional material are used to promote healthy nutritional habits both in school and at home.

Project Spraoi is co-ordinated by a research team consisting of postgraduate students and staff from Cork Institute of Technology. The *Project Spraoi* research consists of several postgraduate-led projects, each with a unique focus on, but not limited to, a particular aspect of PA and/or nutrition. Research conducted by the *Project Spraoi* Research Team includes:

- the evaluation of the effectiveness of a physical activity and nutrition intervention among children from socio-economically disadvantaged schools
- the evaluation of the effectiveness of a physical activity and nutrition intervention on children's sedentary behaviours
- the evaluation of the effectiveness of a physical activity and nutrition intervention on the nutritional habits of primary school children
- the process evaluation of *Project Spraoi*
- the assessment of FMS proficiency among a cohort of Irish primary school children
- the evaluation of the effectiveness of a physical activity and nutrition intervention on markers of health (including body mass index (BMI), heart rate, waist circumference and levels of PA and cardiorespiratory fitness)
- the evaluation of the effectiveness of a motor skill intervention on markers of health (including body mass index (BMI), heart rate, waist circumference and levels of PA and cardiorespiratory fitness)

1.5 Overview of the Study

This thesis consists of two parts. Part I presents the thesis which consists of eight sections, each with its own specific purpose and focus. Part II consists of appendices, incorporating publications to date.

<u>Chapter 1: Introduction</u>

This chapter provides a background to the overall theme of this research, i.e. FMS, including the importance of FMS for sport and PA participation as well for numerous health benefits. An overview of the research conducted in this area to date, both worldwide and more specifically in Ireland, is provided. The aims and hypotheses of the current research are also outlined. This section highlights the importance and significant impact which this research may have on an individual, national and global level. An overview of *Project Spraoi*, the primary school health promotion intervention, of which this research forms one particular branch of investigation, is provided. Finally, a preview of the subsequent chapters of this thesis are included.

Chapter 2: Literature Review

This chapter provides an extensive review of the current literature relating to fundamental movement skills among children including motor skill development, perceived competence, the relationship between FMS and PA and the effectiveness of interventions at improving FMS proficiency among children. Several FMS and perceived competence assessment tools are discussed, with the limitations and strengths of each considered. The current levels of FMS proficiency among children worldwide, assessed using a range of assessment tools, are reviewed. The relationships between FMS, perceived competence and PA are explored, while the tools used in the measurement of perceived competence and PA are also discussed. This section also reviews school-based interventions and their effectiveness in improving FMS among children.

Chapter 3: Methods

This chapter provides a detailed description of the methods adopted to examine the FMS proficiency levels, perceived competence, PA and also those used to evaluate the effectiveness of two different primary school-based interventions aimed at improving children's FMS proficiency. This chapter outlines the procedures used in collection of the following data: anthropometric, FMS, perceived competence and PA. A detailed account of each of the two interventions delivered is also provided including the recruitment process of both schools and children as well as the design, content and implementation of each of the two interventions. Statistical analysis conducted as part of the research is also summarised.

Chapter 4: Worldwide levels of fundamental movement skill proficiency among children, measured using the Test of Gross Motor Development-2: a systematic review[1]

In recent years, and in light of the obesity epidemic and rise in sedentary behaviour among children (Kohl et al., 2012; WHO, 2018a, 2018c), the area of motor skill proficiency among children has received much interest internationally as a potential mechanism to combat these global problems (Logan, Ross, Chee, Stodden, & Robinson, 2018). However, to date, no study has attempted to collate levels of FMS proficiency worldwide to provide a global overview. This systematic review provides an overview of the fundamental movement skill proficiency of primary school aged children (4-13 years) worldwide, assessed using the TGMD-2. This chapter presents a description of each study population and the FMS proficiency score reported as well as the collation of the FMS proficiency levels among the cohorts assessed. The FMS proficiency levels of children reported at each individual age group (ranging from 4-13 years), as well as across several age ranges (including 4-8 years, 8-13 years) and across all the primary school years (4-13 years), were analysed (using a weighted mean analysis approach), providing an indication of the current FMS levels of children worldwide. This chapter also presents evidence-based recommendations to improve the FMS levels of children worldwide.

Chapter 5: Age and sex differences in Fundamental Movement Skills among Irish school children

This chapter presents findings from a cross-sectional study design investigating age and sex differences in FMS proficiency levels among a cohort of Irish primary school aged children. The FMS levels (locomotor subset score, object-control score and GMQ) of 6- and 10-year-old children (both boys and girls) are presented. The study used an analysis of variance (ANOVA) to investigate age and sex differences in FMS proficiency levels. The proportion of children demonstrating proficiency in each of the FMS tested, by age and by sex, was also examined. This chapter also provides a comparison of the FMS proficiency among a cohort of Irish primary school children (by age and sex) with normative data from the United States.

[1] **Note:** While APA referencing style is used throughout this thesis, AMA referencing style has been used for this chapter for ease of reading

The relationship between children's perceived skill competence and MVPA levels was also examined and reported. Hierarchical regression analysis was conducted, for both 6-year-olds and 10-year-olds, to investigate the proportion of variance in MVPA that can be explained by perceived skill competence.

Chapter 7: The effectiveness of two interventions on fundamental movement skill proficiency among a cohort of Irish primary school children

This chapter reports on the effectiveness of two school-based interventions at improving FMS proficiency among children. It provides a detailed description of each of the school-based interventions that were delivered in two intervention schools in the south of Ireland; (i) a PA intervention delivered during the 2014/2015 academic year (AY14/15) and (ii) a multicomponent FMS intervention delivered during the 2015/2016 academic year (AY15/16). A review of existing literature relating to school-based interventions and effective intervention approaches is also provided. Results reported in this chapter include the FMS proficiency levels both prior to, and following, each intervention in addition to those from repeated measures ANOVAs used to examine any intervention and/or interaction effects. Practical implication and recommendations based on the findings are provided as well as the strengths and limitations to the research study.

Chapter 8: Discussion, Conclusion and Recommendations for Future Research

This chapter consists of an overarching discussion and conclusion for this research study in its entirety. This includes the presentation of findings from a process evaluation of the interventions implemented, which was conducted as part of a parallel study within *Project Spraoi* (O'Bryne, Coppinger, Dineen, & O'Neill, 2018). Practical implications based on the findings of this research are suggested and discussed. The strengths and limitations of the research are identified, with recommendations for future research also provided. The remainder of the document contains a list of all literature referred to within the research.

Appendices (incorporating publications to date)

Publications to date include one article which has been accepted for publication. Two further articles are currently under review. Conference papers and a conference poster are also included. All publications are presented in Appendix A. Due to the nature of this research, there was a significant volume of additional material used during the research. This additional material is included on the enclosed CD-ROM (Appendices B-F).

Given that high levels of physical inactivity and overweight/obesity have been reported among Irish children (Woods et al. 2010), potential ways to improve the status of both are warranted. Research reports that FMS levels are positively associated with PA levels and negatively related to weight status (Lubans et al., 2010), which suggests that the development of FMS may have the potential to improve PA levels and reduce the prevalence of overweight/obesity. Currently, there is a dearth of literature relating to the FMS proficiency of Irish primary school children. However, research among Irish adolescents (O'Brien et al., 2013) indicates that FMS proficiency among this cohort is low, suggesting that the FMS levels of Irish primary school children may also be low. Interventions have been shown to have a positive impact on children's FMS (Logan et al., 2011; Morgan et al., 2013; Tompsett et al., 2017). However, no such intervention has been designed, delivered or evaluated in an Irish primary school context. An aim of the current research was to examine the FMS proficiency of a cohort of Irish primary school children and subsequently design and deliver an effective intervention to improve it. Thus, an overview of literature relating to FMS, its associated health benefits, current FMS levels worldwide and interventions that have measured FMS as an outcome in their evaluation is provided in the following chapter.

Chapter 2:

Literature Review

2.1 Introduction

This literature review will present as five distinct, but related, sections. Section 1 serves to provide an overview of FMS and furthermore discusses several motor skill assessment tools incorporating the review of the psychometric properties and strengths/weaknesses associated with each respective tool. Section 2 outlines the importance and benefits associated with FMS proficiency including an overview of findings investigating the relationships between FMS and markers of health. Section 3 provides an in-depth review of various motor development models with a particular emphasis on the fundamental movement skill phase. Models presented in this section include Gallahue's Triangulated Hourglass Model of Motor Development (incorporating Gallahue and Ozmun's Hourglass Model and Newell's Theory of Constraints) (Gallahue et al., 2012) as well as Clark and Metcalfe's Mountain of Motor Development Metaphor (Clark & Metcalfe, 2002). Section 4 presents an overview of studies that have assessed the FMS proficiency levels among primary school children worldwide, with an insight provided into existing age and sex-related differences in FMS proficiency in addition to the current levels among Irish primary school children. Finally, Section 5 describes school-based interventions, both PA-based and FMS-based, which have been implemented among children worldwide and reviews the effectiveness of such interventions in improving the FMS proficiency of children. Effective FMS intervention strategies are discussed and an overview of FMS interventions delivered among Irish children is also provided.

For this literature review, recent and relevant studies were identified by searching the following electronic databases: ScienceDirect, PubMed and SportsDiscus, with studies published after 2003 included. The reference lists of identified articles were also screened for additional relevant articles, which were also included. Key terms used in the search included: fundamental movement skill*, motor skill*, motor development, children, youth, intervention, primary school, elementary school, validity, reliability. Following the search, duplicates were removed and the title and abstract of the remaining retrieved files screened. Inclusion criteria required participants to: (i) typically developing (articles that focus on children from special populations were not included e.g. overweight/obese, development coordination disorder, low-socio-economic status), (ii) have motor competence evaluated, (iii) be aged between four and 13 years. Relevant books, book chapters and unpublished theses were also included in the literature review.

2.2 Fundamental Movement Skills (FMS)

Fundamental movement skills, or fundamental motor skills known as FMS, are basic observable patterns of movements such as running, jumping, catching and striking among many others (Gallahue et al., 2012). FMS are regarded as the 'building blocks' required for the acquisition of more complex, sport-specific movements and facilitate participation in games, sports and physical activity (Clark, & Metcalfe, 2002; Gallahue & Ozmun, 2006; Logan et al., 2011). Support for this consideration of FMS as 'building blocks' has been provided in the research (O'Keeffe, Harrison, & Smyth, 2007; Reid, Giblin, & Whiteside, 2015). A study conducted by O'Keeffe, Harrison and Smyth (2007) found that the overarm throw formed the 'building block' and facilitated transfer to the badminton overhead clear and javelin throw. Results revealed significant improvements in the both these sport-specific skills following a 3 week period of overarm throwing training (2 x 30 sessions each week) and a 2 week period of no practice (i.e. at retention). Transfer from the overarm throw was 26% and 57% for the badminton overhead clear and javelin throw, respectively. Furthermore, Reid, Giblin and Whiteside (2015), who conducted a kinematic comparison of the overhand throw and tennis serve, reported that similar preparatory mechanics were used in the performance of the overarm throw and tennis serve. While research investigating the transferability of FMS to sport-specific skills is limited, Miller (2007) suggests that further research may confirm that other FMS transfer to other sport-specific skills.

FMS also form a key component in the development of physical literacy (Barnett, Stodden et al., 2016; Lundvall, 2015), which is defined by as *"the motivation, confidence, physical competence, knowledge and understanding to maintain physical activity throughout the life course"* (Whitehead, 2010, p.5). Although often misinterpreted as physical literacy, FMS are an important element of this construct, directly contributing to the physical competence aspect of physical literacy as well as influencing one's motivation and confidence through perceived FMS competence, with positive associations also found between FMS and physical activity levels and health benefits (Barnett, Stodden et al., 2016; Barnett et al., 2009; Lubans et al., 2010).

FMS are classified into three categories: locomotor, object-control (or manipulative) and stability skills (Lubans et al., 2010). Locomotor skills involve the movement of the body from one location to another (e.g. running, jumping, hopping, galloping, sliding). Object-control or manipulative skills are those involving the application of force to, or from, objects (e.g. throwing, catching, dribbling). Stability skills referred to as the most basic FMS, include any movement requiring balance or posture or any non-locomotor or non-manipulative skill (e.g. dodging, twisting, turning, body rolling) (Lubans et al., 2010). Often, stability or balance skills, due to the core role they play in the performance of the other FMS, are sometimes considered underlying abilities as opposed to a specific FMS category (Burton & Rodgerson, 2001; Fleishman, 1962; Fleishman, Quaintance, & Broedling, 1984). Many movements or sports require a combination of skills from one or more of the different categories. For example, playing basketball requires locomotor skills (running and jumping), object-control skills (catching, throwing, dribbling) and stability skills (balance, dodging, turning and twisting) (Gallahue & Ozmun, 2006).

Proficiency in FMS is often discussed in terms of 'mastery'. The term 'mastery' is defined as 'comprehensive knowledge or skill in a particular subject or activity' (Oxford University Press, 2018). However, there is no consensus as to what quantifiable level of FMS performance classifies as 'comprehensive'. For example, could mastery be determined by whether an individual can produce the desired outcome of a skill irrespective of the technique? For example, can an individual catch a ball irrespective of the technique used? Or could mastery be defined as performing greater than 85% of the skill components (equivalent to an A grade) correctly? Some FMS assessment tools define what mastery is in terms of their test. For example, when using the TGMD-2, 'mastery' of a component requires the component to be present in both of the test trials performed during the test, while 'mastery' of a skill required that all components of a skill be present across the two test trials. In contrast, the Get Skilled: Get Active requires that a component be present in four out of five trials for the skills to be consider 'mastered' while the FMS-A Manual for Classroom Teachers (Department of Education Victoria, 1996) only requires it to be present in four out of six trials. However, this inconsistency makes it difficult to define what mastery actually is in terms of FMS. Furthermore, a resource developed by the Department of Education, Western Australia (Department of Education WA, 2013) in contrast to other FMS assessment tools, assesses children's competence not only in formal testing sessions where the presence of a number of pre-defined components can be examined across a specific number of trials but also through informal observations and in different settings and contexts.

Also, if children fail to achieve 'mastery' as defined by a particular assessment tool, there is a lack of understanding or classification as to their exact level of performance relative to the desired 'mastery' e.g. near mastery, 50% proficient or perhaps classified as exhibiting developmental delay. Therefore, as a lack of clarity as to the definition and understanding of mastery in terms of FMS performance and competence exists, a global definition of 'FMS mastery' is warranted.

In recent times, it has been argued that FMS are not all fundamental (Almond, 2014; Pot & van Hilvoorde, 2014). Research conducted by Giboin, Gruber and Kramer (2015) highlights this issue as it was reported that individuals who had received balance training (a skill considered to be fundamental and included in numerous test batteries) improved their performance in task-specific skills with no improvement in non-specific tasks. However, Barnett and colleagues (2016) argue that FMS are 'fundamental', described as forming a necessary core or basis for more advanced, sport-specific skills. Specific components or patterns necessary to perform a FMS are also required and can be observed in the performance of these sport-specific skills facilitating participation in various sports and physical activities. For example, all/some elements required to perform the throw (an object-control FMS) are required to execute a tennis serve, netball shoulder pass, a throw in cricket (Gallahue et al., 2012), and a badminton clear (O'Keeffe, Harrison, & Smyth, 2007). Similarly, elements of the leap and hop are combined and applied to successfully perform the triple jump (track and field event) (NSW Department of Education and Training, 2000).

It has also been critiqued that skill transfer is limited, with each skill leading to a limited number of activities (Almond, 2014; Pot & van Hilvoorde, 2014). However, while each skill may be directly transferrable to certain sports/activities, the underlying attributes of these skills may transfer to a vast range of sports/activities (Barnett, Stodden et al., 2016). Proficiency in FMS requires a high degree of functional coordination and control including the development of dynamic balance, optimal timing of component execution, contralateral coordination of the limbs, perceptual-motor abilities, optimal inter- and intra-muscular coordination and efficient transfer of energy through the kinetic chain (Barnett, Stodden et al., 2016). These elements can be transferred to, and are essential for, many movements and more advanced skills. Movement skills develop in a sequential manner (Department of Education, Victoria, 1996) and failure to achieve FMS competency presents a 'proficiency barrier' to the development and acquisition of more advanced, specialised sport-specific skills (Seefeldt, 1980; Stodden et al., 2008), as well as higher PA levels (De Meester et al., 2018) and greater health-related fitness (Stodden, True, Langendorfer, & Gao, 2013).

Questions have also been raised surrounding the selection of skills that are considered 'fundamental' (Almond, 2014; Pot & van Hilvoorde, 2014). Different FMS assessment tools have been developed worldwide, testing slightly different types and forms of skills (Cools, Martelaer, Smaey, & Andries, 2009). While test developers are required to make a number of decisions such as how many skills to include, how many test performances to use for analysis, what scoring protocols to use, they must also decide what skills and what skill components will best represent the skill competence of a child. FMS assessment tools/test tend to include FMS that may later transfer to culturally specific sport skills. For example, the TGMD-2 which was developed in the United States includes skills that are culturally relevant among the US population. As such, the skill components necessary for the stationary strike mirror those used in the performance of the strike in baseball, a popular sport in the US. In Ireland, the skills and components of the TGMD-2 in 11 of the 12 skills can be applied in an Irish context, but not for the strike. The strike technique of the TGMD-2, which mirrors the fundamental technique required for a baseball strike is different to that required in hurling/camogie (a striking sport, one of the national games of Ireland), which requires a different hand-grip. As a result, proficiency levels in the strike may be influenced by children's exposure to hurling/camogie. Therefore, while many skills are integrated in common sports (e.g. running, kicking), cultural relevance and the popular activities in different countries must be considered when deciding what 'fundamental' skills are most applicable to the population and which measurement tool is most appropriate.

A further critique or objection to the promotion of FMS as a primary pedagogical focus is that the teaching of FMS often becomes the teaching of the FMS 'test' i.e., in a closed, isolated setting, which may limit children's ability to adapt and use the skill in other contexts. However, for children to be able to perform FMS or related skills in different contexts or sporting situations, they must first be able to master the skill in a closed environment. For example, how can an individual catch a ball in a hurling/rugby/basketball match (while also running with an opponent approaching them) if they cannot successfully catch a ball while stationary without opposition? Therefore, while rudimentary levels of some FMS may be developed through exploring, practice and the availability of opportunities and facilities, FMS development required quality instruction, practice and feedback. Several systematic reviews have provided evidence for the effectiveness of motor skill interventions, with improvements in FMS found to be greater than those made through free-play (Iivonen & Sääkslahti, 2013; Logan et al., 2011; Morgan et al., 2013). However, to optimise the learning of FMS for use in different sporting and physical activity related setting, Smith (2016) suggests that FMS and fundamental games skills should be taught in complementary ways to children at all developmental stages.

2.2.1 Motor Competence Assessment Tools

In order to monitor and evaluate the development of FMS, several assessment tools have been designed and developed. This section outlines several movement assessment tools, including both process- and product-oriented measurement tools, used to assess

FMS. Process-oriented assessment tools are those which evaluate ‘how’ a movement is performed (i.e. technique used) and involve the identification of qualitative patterns of movement (Logan, Barnett, Goodway, & Stodden, 2017). Examples include the TGMD-2 (Ulrich, 2000), TGMD-3 (Ulrich, 2013), Get Skilled Get Active (NSW Department of Education and Training, 2000) and the Department of Victoria Manual for Classroom Teachers (Department of Education, Victoria, 1996). On the other hand, product-oriented assessment tools evaluate the ‘outcome’ or ‘end-result’ of a movement, which often involves quantitative score (e.g. distance, time to completion) (Logan et al., 2017). Examples of product-oriented tools include the Movement Assessment Battery for Children (MAB-C) (Henderson & Sugden, 1992), the Movement Assessment Battery for Children - Second Edition (Henderson, Sugden, & Barnett, 2007) and the KörperkoordinationsTest für Kinder (KTK - Kiphard & Schilling, 1974, 2007). Some assessment tools, such as the Bruininks-Oseretsky Test of Motor Proficiency (Bruininks, 1978) are both process- and product-oriented tools that evaluate both the qualitative aspects of a movement as well as the outcome of the movement. Several commonly used assessment tools are reviewed below, which vary in the following aspects:

- the aspects of movement competence assessed,
- number of skills/items assessed,
- duration of test administration,
- scoring protocol,
- scoring interpretation
- strengths and weaknesses of the test and
- the psychometric properties (i.e. validity and reliability) of the test for administration among a child population.

<u>The Movement Assessment Battery for Children – Second Edition</u>

The Movement Assessment Battery for Children – Second Edition (MABC-2) (Henderson et al., 2007) is a revised version of the Movement Assessment Battery for Children (Movement ABC or MAB-C) (Henderson & Sugden, 1992). The MAB-C is a commonly used norm-ranked measure in the screening of Developmental Co-Ordination Disorder (DCD) in school-aged children (Geuze, Jongmans, Schoemaker, & Smits-Engelsman, 2001). was designed to identify motor skill deficits and impairments among children as opposed to evaluating the motor proficiency of children (Johnston & Watter, 2006). The MAB-C, which itself is a revised version of the Test of Motor Impairment (TOMI), has been reported to have good test-retest reliability, with an intra-class correlation (ICC) of .75, based on that established by three evaluators for the TOMI (Croce, Horvat, & McCarthy, 2001; Henderson & Sugden, 1992), examining a cohort of 360 children. Test-retest reliability reported for each respective age group was .75 (among 4- to 6-year-old group), .43 (among 6- to 8-year-old group), .96 (among 9- to 10-year-old group) and .97 (among 11- to 12-year-old group) (Cools, De Martelear, Samaey, & Andries, 2009). Also, inter-rater reliability between three evaluators for the Test of Motor Impairment has been reported with an ICC of .70 (between 62-100% matched between raters), based on a sample of 360 children (Cools et al., 2009). The MAB-C has also been reported to have moderate concurrent validity with the BOTMP (r = .53; large correlation) (Crawford, Wilson, & Dewey, 2001) and with the KTK (r = .62; large correlation) (Cools et al., 2009).Based on performance, a quantitative score ranging from 0 to 5 (with lower scores indicating better performance) is awarded for each task as well as a rating of qualitative aspects (e.g. posture) of movement included in a checklist, in which each item is classified using standard indicators. Each of the three subsection scores are calculated by summing the items scores within each subsection, with subsection scores subsequently summed to provide a total impairment score and an indication of overall performance. A comparison of these scores to normative data can be made to assess if the performance within each subsection and overall is: (i) normal (ii) at-risk or (iii) definitely impaired (Henderson & Sugden, 1992).

In contrast to the MAB-C, which is applicable to children aged 4-12 years of age, the MABC-2, is applicable across both children and adolescents (3-17 years) and utilises normative scales based on a larger, more representative sample than that in the MAB-C. Other differences include:

- the addition of four test items
- the revision of several existing items
- the development a ‘Traffic Light system’ to assist scoring interpretation
- adjustments to the specific age bands to include a wider age range

The MABC-2 consists of two elements: a Performance Test and a Checklist. Similar to the MAB-C, the Performance Test consists of tasks covering the areas of manual dexterity, aiming and catching, and balance. The Checklist is a 30-item scale that the test administrator must complete based on the children's motor competence during the tasks (Brown & Lalor, 2009; Henderson et al., 2007).

A major weakness of the MABC-2 is the limited evidence of its reliability and validity. The authors of the MABC-2 suggest that the psychometric properties of the MAB-C are adequate and generalisable to the MABC-2 and therefore, limited data regarding its reliability is provided in the test manual. However, it is believed that due to the modifications made in the revision of the tool, more evaluation is necessary (Brown & Lalor, 2009). Some reliability data is available for the MABC-2 (Chow, Chan, Chan, & Lau, 2002; Faber & Nijhuis van der Sanden, 2004; Visser & Jongmans, 2004), however several issues including the cultural context, language translation of test items and the evaluation of selected age bands only, questions the quality of these findings. The test manual also provides limited information regarding the validity of the MABC-2. While content validity (established by an expert panel) and face validity has been reported to have been established, face validity evidence appears to have been based on the MABC. Section (Manual Dexterity, Aiming and Catching, and Balance) and total test score correlations are provided in the test manual to demonstrate the relatedness of the subsections within the test (Brown & Lalor, 2009). The Manual Dexterity section is reported to be correlated with the Aiming and Catching section (.26), Balance section (0.36), and total test score (.76). The Aiming and Catching section is reported to be correlated with the Balance section (.25), and total test score (0.65). The Balance section was also correlated with total test score (.73) (Brown & Lalor, 2009).

Criterion-related validity was established and reported in three different studies for the MABC-2. In a study by Kavazi (2006), the relationship between the MAB-C and the Goodenough and Harris Draw-a-Man Test was examined, with correlations of .66 reported. However, only the Manual Dexterity items from one specific age band were examined among a small sample size. Notably, this study was not been peer-reviewed. A second study involved the use of the MABC-2 to re-assess 20 children who had previously been found to exhibit a motor impairment using the MAB-C, which revealed similar findings (Henderson et al., 2007). A final validation study (Siaperas, Holland, & Ring, 2006), which was proposed as evidence of discriminative validity, examined 25 boys with Asperger Syndrome (a childhood developmental disorder with which movement difficulties have been associated) (Nayate, Bradshaw, & Rinehart, 2005) and found 21 of the 25 boys exhibited a motor impairment. However, as this study which is not peer-reviewed nor published, did not include a matched control group and therefore, the claim that this study is evidence of discriminative validity cannot be supported (Brown & Lalor, 2009). In terms of construct validity, there is no evidence reported for either the Performance Test or the Checklist (Brown & Lalor, 2009).

Therefore, while the MABC-2 is a screening tool which has been used to determine the presence of motor impairments, practitioners, teachers and parents must be cautious when interpreting the outcome of the test until adequate reliability and validity has been established.

KörperkoordinationsTest für Kinder (KTK)

The KörperkoordinationsTest für Kinder (Body Coordination Test for Children) or KTK (Kiphard & Schilling, 1974; 2007), is a product-oriented test, developed to assess gross motor coordination among 5- to 14-year-old children. The KTK is easy to administer, takes approximately 15 minutes per child and consists of the following four subtests:

- walking backwards on three different balance beams of various widths: 6cm, 4.5cm and 3cm (WB),
- moving sideways using wooden boxes for 20 seconds (MS),
- hopping for height over an increasing number of 5cm foam blocks (HH)
- jumping sideways with feet together over a wooden slat for 15s (JS)

Raw scores for each of the four subtests are converted to motor quotients (MQ), which can then be compared to normative scores, standardized based on age and sex. MQ scores are summed and converted to give a total MQ score, providing an indication of a child's overall gross motor coordination (Iivonen, Saakslahti, & Laukkanen, 2015; Kiphard & Schilling, 1974, 2007). This score is used to classify children into one of five categories: impaired, poor, normal, good and high. Normative scores were established based on the performance of 1228 normally developing German children from 1974 (Kiphard & Schilling, 1974).

The psychometric characteristics of the KTK have been established and reported (Kiphard & Schilling, 1974, 2007). The test, as a whole, has good-to-excellent test-retest reliability (*r* > .85) and inter-rater reliability (*r* > .85) as well as sufficient reliability for each subtest (*r* values; WB: .80, MS: .84, HH: .96, JS: .95). Content and construct validity have been established among children (Kiphard & Schilling, 1974), with intercorrelations and factor analysis used. Total variance of the KTK explained by the subtests ranged from 81% (among 6-year-olds) to 98% (among 9-year-olds), indicating high content validity. In addition, factor analysis revealed that each individual subtest loaded on the same factor, gross motor coordination. Intra-correlations between the four subtests ranged from .60 (WB/JS) to .81 (HH/JS) (Iivonen et al., 2015; Kiphard & Schilling, 1974, 2007).

Limitations of this tool include its inability to determine locomotor and/or object-control proficiency (with only an overall value representative of gross motor skill proficiency produced) and also normative scores are based on a German population only, with value obtained over 40 years ago (Cools et al., 2009).

<u>FMS: A Manual for Classroom Teachers</u>

The Fundamental Motor Skills Assessment included in the 'FMS: A Manual for Classroom Teachers' resource was developed by the Department of Education Victoria (1996) to evaluate motor skill performance of students and also to to inform teachers and assist them in the teaching and learning of motor skills. The tests consists of 11 fundamental movement skills, each consisting of between 5-8 performance components. The skills include the catch, kick, vertical jump, overhand throw, ball bounce, leap, dodge, punt, one-handed forehand strike, and two-handed side-arm strike. In the scoring of each skill, a score of '1' is awarded for the correct performance of each skill component. If a child performs all components of a skill correctly, they are considered to have 'mastered' or to be a 'master' of this skill. For each skill within the assessment, standards are provided, indicating the age at which each component is expected to be mastered, as well as the order in which the components tend to be acquired during development.

There is limited evidence for the validity and reliability of this testing tool. However, test-retest reliability estimates (alpha coefficients) reported for each of the 11 individual skills ranged from .13-.95 (catch: .92, overhand throw: .92, kick: .78, punt: .86, forehand strike: .95, two hand side-arm strike: .90, ball bounce: .94, run: .17, leap: .13, dodge: .70, vertical jump: .74) (Department of Education, Victoria, 1996). These reliability estimates were found to be statistically significant ($p<0.01$) for all skills except the run and the leap, both of which had low test-retest reliability. A limitation to this evidence is use of small sample, which consisted of a group of 42 children (3 boys and 3 girls from each grade from Preparation to Year 6), three of whom did not complete the re-test assessment. Furthermore, there is no information in relation to the number of assessors involved in the scoring of these performances (i.e. coders) which were used in this analysis nor the level of expertise of these coders in scoring FMS performances. In addition, it is not reported whether FMS performances were scored live on site or retrospectively using video recordings. As the run is performed as fast as possible by each child and as only one leap is performed per trial according to test manual, live scoring of performances may have influenced the findings for these two skills. Nonetheless, with such low test-retest reliability for both the run and leap, the inclusion of these skills as part of this test battery is questionable. Further reliability testing is recommended. Another weakness is the absence of a normative dataset. However, the test provides a qualitative assessment of movement across a wide range of skills and provides ‘standards’ or an indication of the age and sequential order in which skill component may develop.

<u>Test of Gross Motor Development-Second Edition (TGMD-2)</u>

The Test of Gross Motor Development-2 (Ulrich, 2000), a revised version of the original Test of Gross Motor Development) (Ulrich, 1985), is a criterion- and norm-referenced process-oriented tool, designed to assess the FMS proficiency of children aged three to 10 years. Normative sample data was collected between 1997 and 1998 and is based on the performances of 1208 children from 10 states in the United States, with demographics representative of the school-aged population of the US. The TGMD-2 takes approximately 15-20 minutes to administer and consists of 12 FMS, divided into two subsets of skills; locomotor and object-control. The six locomotor skills assessed are the run, gallop, slide, leap, hop and horizontal jump. The six object-control skills assessed are the kick, catch, overhand throw, strike, underhand roll and dribble.

Each of the 12 FMS consist of 3-5 behavioural components. If a component is performed correctly, a score of 1 is awarded. If the behavioural component is performed incorrectly, a score of 0 is awarded. This procedure is repeated for each component of a skill across two test trials. Scores from both trials are summed to obtain a raw skill score (Ulrich, 2000). 'Mastery', as defined by the TGMD-2, of a FMS is achieved when all components of a skill are present (i.e. skill performed correctly) across both test trials. Locomotor and object-control subset scores are calculated by summing the raw scores of the individual skills within each subset (Locomotor Score Range: 0-48; Object-control Score Range: 0-48). Subset scores are converted, based on age and sex, to standard scores (LSS and OCSS) using conversion tables outlined in the TGMD-2 manual. The best measure of overall FMS proficiency is the Gross Motor Quotient (GMQ). The sum of the subset standard scores is converted (as outlined in the TGMD-2 conversion tables), based on age and sex, to obtain the GMQ (Figure 2.1).

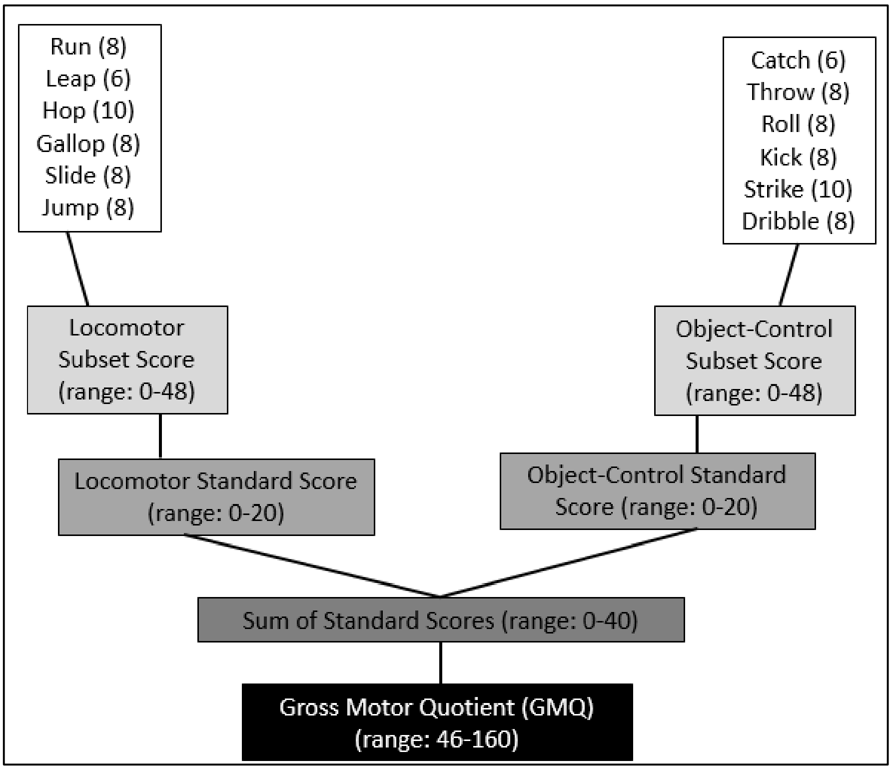

Figure 2.1: Scoring Protocol of the TGMD-2 (Ulrich, 2000)

LSS, OCSS and GMQ can be used to categorise the locomotor, object-control and overall FMS performance of each child into one of seven categories, ranging from very poor to very superior. Children with a standard score (LSS/OCSS) between 1-3 are classified as 'very poor', between 4-5 classified as 'poor', 6-7 as 'below average', 8-12 as 'average', 13-14 as 'above average', 15-16 as 'superior' and 17-20 as 'very superior' in terms of locomotor/object-control proficiency (Ulrich, 2000). A similar scoring protocol was used to classify the overall FMS proficiency of children using the GMQ (*very poor*: <70; *poor*: 70-79; *below average*: 80-89; *average*: 90-110; *above average*: 111-120; *superior*: 121-130; *very superior*: >130) (Ulrich, 2000) (Table 2.1). Mean percentile and age equivalent scores can also be derived using the raw test scores. Mean percentiles, or percentile rank, represent the proportion of the normative sample who achieved a value equal to or below the associated score. For example, a percentile of 60 means that 60% of the normative sample scored less than or equal to the performer's score. Age equivalent scores use subset scores to provide an estimated developmental age based on a child's performance (Ulrich, 2000).

Table 2.1: TGMD-2 Descriptive Rating Categories (adapted from Ulrich, 2000)

FMS Category	Standard Score (SS)	Gross Motor Quotient (GMQ)
Very Superior	17-20	>130
Superior	15-16	121-130
Above Average	13-14	111-120
Average	8-12	90-110
Below Average	6-7	81-90
Poor	4-5	71-80
Very Poor	1-3	<70

Mastery is only achieved when all components across all skills are performed correctly (i.e. a child is awarded a total FMS score of 96/96) (Ulrich, 2000). To achieve this, children must be awarded a 48/48 for both locomotor and object-control subsets. When a locomotor subset score of 48 is converted to a subset standard score, 'mastery' ranges from a score of 13 (for children aged 9 years through 10 years 11 months) to 20 (for children aged 3 years through 3 years 5 months), i.e. for a 3 year old boy, a locomotor score of 48 equates to a locomotor standard score of 13, and thus mastery for the locomotor skills. Similarly, when an object-control subset score of 48 is converted to a subset standard score, 'mastery' ranges from a score of 13 (for boys aged 9 years through 10 years 11 months) to 20 (for girls aged 3 years through 5 years 5 months and boys aged 3 years through 4 years 5 months). When subset standard scores (corresponding to mastery in each respective subset) are summed and converted based on age and sex to GMQ score, 'mastery' (i.e. maximum GMQ score for a given age and sex) across all 12 FMS ranges from 118 (for boys aged 10 years through 10 years 11 months) to 160 (for children aged 3 through 3 years 5 months). This maximum GMQ score, which is age- and sex-specific, corresponds to a TGMD-2 rating category displayed in Table 2.1. In Table 2.2, the maximum GMQ score possible for each specific age and sex are presented, as well as the corresponding TGMD-2 category into which a child is categorised if mastery across all skills is achieved. As is evident from the table, the relationship between mastery and TGMD-2 classifications are age and sex-specific.

Table 2.2: The relationship between TGMD-2 mastery and GMQ classification for 3-10 year olds

Age (years-months)	Sex	Max GMQ	Max classification
3-0 through 3-5	Girls	160	Very Superior
	Boys	160	Very Superior
3-6 through 3-11	Girls	160	Very Superior
	Boys	160	Very Superior
4-0 through 4-5	Girls	160	Very Superior
	Boys	160	Very Superior
4-6 through 4-11	Girls	160	Very Superior
	Boys	157	Very Superior
5-0 through 5-5	Girls	157	Very Superior
	Boys	151	Very Superior
5-6 through 5-11	Girls	151	Very Superior
	Boys	145	Very Superior
6-0 through 6-5	Girls	145	Very Superior
	Boys	139	Very Superior
6-6 through 6-11	Girls	142	Very Superior
	Boys	133	Very Superior
7-0 through 7-5	Girls	136	Very Superior
	Boys	127	Superior
7-6 through 7-11	Girls	130	Superior
	Boys	124	Superior
8-0 through 8-5	Girls	124	Superior
	Boys	118	Above Average
8-6 through 8-11	Girls	124	Superior
	Boys	118	Above Average
9-0 through 9-5	Girls	124	Superior
	Boys	124	Superior
9-6 through 9-11	Girls	124	Superior
	Boys	118	Above Average
10-0 through 10-11	Girls	124	Superior
	Boys	118	Above Average

The TGMD-2 has been found to be valid and reliable among children aged 3-10 years (Ulrich, 2000). Content description validity was established following the unanimous judgement of three content experts and conventional item analysis using the item discrimination index. Criterion-prediction validity of the test was also reported, with a moderate-to-strong correlation between test subsets and criterion variable (the Basic Motor Generalizations subtest of the Comprehensive Scales of Student Abilities (CSSA)) (Locomotor: r = .63, Object-control: r =.41, Total composite: r = .63). Results also support the construct-identification validity of the TGMD-2, with the following underlying constructs tested: age differentiation, group differentiation, item validity, subtest correlations and factor analysis. In terms of reliability, content sampling, time sampling and inter-rater differences were evaluated to assess the amount of error associated with each subtest as well as GMQ score. Reliability coefficients (assessed using Cronbach alpha for subsets and Guilford's formula for GMQ) ranging from .85 - .91 were found for content sampling. High test-retest reliability (ranging from .88 - .93) and inter-rater reliability (.98 for all) across subsets and GMQ are also associated with the TGMD-2 (Ulrich, 2000).

Test of Gross Motor Development – 3rd edition (TGMD-3)

The Test of Gross Motor Development – 3rd edition (TGMD-3) has recently been developed, and includes 13 FMS (Ulrich, 2013). In contrast to the TGMD-2, this recent revision of the tool includes the skip, forehand strike of a self-bounced ball and the underhand throw, while the leap and roll are no longer assessed. Locomotor skills assessed are the run, gallop, hop, skip, horizontal jump and slide. Ball skills include the two-handed strike of a stationary ball, forehand strike of a self-bounced ball, one hand stationary dribble, two handed catch, kick of a stationary ball, overhand throw and underhand throw. Both the administration and scoring protocol of the TGMD-2 is retained in the TGMD-3. Several adaptations have been made to the TGMD-2 in a number of skills, regarding the performance criteria required, which are displayed in Table 2.3.

Table 2.3: Adaptations to performance criteria of the TGMD-2 included in TGMD-3

Skill	TGMD-2	TGMD-3
Hop	Takes off and lands three consecutive times on preferred foot. Takes off and lands three consecutive times on non-preferred foot.	Hops four consecutive hops on preferred foot before stopping
Jump	Arms extend forcefully forward and upward reaching full extension above the head	Arms extend forcefully forward and upward reaching above the head
Slide	A step sideways with the lead foot followed by a slide of the trailing foot to a point next to the lead foot	A step sideways with the lead foot followed by a slide with the trailing foot where both feet come off the surface briefly
Two-handed strike	Non-preferred side of the body faces the imaginary tosser with feet parallel. Transfers body weight to front foot. Bat contacts ball	Child's non-preferred hip/shoulder points in direction of straight ahead. Step toward ball with non-preferred foot. Hits ball sending it straight ahead.
Stationary dribble	Ball contacts surface in front of or to the outside of foot on preferred side	Component not included
Kick	Kicks ball with instep of the preferred foot (shoe-laces or toe)	Kicks ball with instep of preferred foot (not the toes)

Normative data collection for the TGMD-3 has recently been completed, with publication of the TGMD-3 expected in the near future. The evaluation of the psychometric properties of the TGMD-3 revealed high levels of validity and reliability for the tool (Webster & Ulrich, 2017). The test was conducted among 807 children (mean age: 6.33 ± 2.09 years). Reliability testing revealed that correlations with age were moderate to large, with higher correlations found with ball-skills (r = .47, medium correlation) compared to locomotor skills (r = .39; medium correlation). Internal consistency in each age group was found to be very high, as well as for both sexes and all racial/ethnic groups. High test-retest reliability was also found for both subsets (ICC for locomotor: .97, ICC for ball skills: .95) and total TGMD-3 (ICC: .97). Validity measures, including item difficulty (range: .43 - .91) and item discrimination values (.34 - .67) were reported to be above adequate and results from factor analysis indicate adequate construct validity for the TGMD-3 (Webster & Ulrich, 2017).

Get Skilled: Get Active

The Australian 'Get Skilled: Get Active' resource/checklists (NSW Department of Education and Training, 2000) is a qualitative assessment tool evaluating proficiency in

12 motor skills including the sprint run, leap, dodge, vertical jump, hop, side gallop, skip (all locomotor skills), catch, overhand throw, kick, forehand strike (all object-control skills), and static balance (stability skill). For each skill, a number of introductory performance criteria (either two or three) as well as additional fine-tuning components (between 2-4) are provided, allowing skills to be assessed at two different levels of difficulty. A score of 1 is awarded if a component is present during a performance. Depending on the level of difficulty as well as the number of skills chosen to be assessed, a total skill, subset and overall test score can be obtained.

Test re-test reliability has been examined with children from Grades 1-3 using different combinations of six skills (Okely & Booth, 2000). Mean agreement scores (%) ranged from 69 (for the hop with Grade 1 children) to 85 (for the kick with Grade 3 children) (Barnett, Morgan, van Beurden, Ball, & Lubans, 2011). A major weakness of the Get Skilled: Get Active resource is the limited evidence available in relation to its reliability and validity. Checklists included in the resource also fail to provide guidelines to the number of trials that are required and/or if scores across performances should be summed or if the best performance should be used as an indicator of proficiency level. Furthermore, normative data is not provided with this resource.

In summary, although there are many useful assessment tools available, to select the most suitable motor skill assessment tool, it is necessary to consider the following:

- purpose of the assessment (evaluation of current levels of FMS, identification of motor delays, evaluation of treatment programme)
- the aspect of movement competence being assessed (e.g. FMS, motor coordination, fine motor skill proficiency)
- sample population
- available time
- available evaluators
- available resources (e.g. equipment, space)
- reliability and validity of the tool
- adequate normative data based on sample characteristics and demographics
- strengths and limitations of the tool

Table 2.4 provides a summary and overview of all the assessment tools that have been described. For this research, the TGMD-2 was selected as the most appropriate assessment tool as (i) it is a process-oriented tool, allowing for a qualitative analysis of movement, (ii) it has been shown to be valid and reliable among children of similar age to the participants included in the current research, (iii) many of the skills are applicable in an Irish context and (iv) it is easy to administer. The availability of normative data also allows comparisons to be made with US children of similar age and sex.

Table 2.4: A summary of six motor skill assessment tools including: the availability of normative data, assessment type, reliability, and validity

Tool	Purpose	Age	Normative Data		Assessment Type		Reliability	Validity
			Y/N	Sample	Product	Process		
MABC-2	Identify motor deficits and impairments	3-17	Y	1172 children from the United Kindgom	Y	Y	Limited; Suggested that reliability of the MAB-C are generalisable to the MABC-2: Test-retest reliability for the TOMI, n=360, 3 raters: ICC = .75; .64 (4- to 6-year olds), .43 (6- to 8-year-olds), .96 (9- to 10-year-olds), .97 (11- to 12-year-olds) Inter-rater reliablity reported for the TOMI, n=360, 3 raters: ICC = .70, 62-100% match between raters However due to the modificiations made in the revised version, further evaluation required	Limited; Content validity established, expert panel Face validity (established by feedback from professionals) appears to be based on MABC Relatedness of subsets: Manual Dexterity and - Aiming and Catching r = .26 - Balance r = .36 - Total test score r = .76 Aiming and Catching and - Balance r = .25 - Total test score r = .65 Balance and - Total test score r = .73 Suggested that validity of the MAB-C is generalisable to the MABC-2: Concurrent validity with BOTMP r = -0.53 (large correlation) and with KTK r = .62 (large correlation) Criterion-related validity (reported by individual studies - neither published or peer-reviewed): MABC-2 (Manual Dexterity only, one Age-Band only) with the Goodenough and Harris Draw-a-Man Test, n = 31 Cypriot children, r = .66 (Kavazi, 2006) Discriminative validity: Re-assessment of 25 children with Asperger Syndrome identified 21 of the children with impaired motor skills. However, no matched control group.

Tool	Purpose	Age	Normative Data		Assessment Type		Reliability	Validity
			Y/N	Sample	Product	Process		
KTK	Assess gross motor coordination	5-14	Y	1228 German children in 1974	Y		Inter-rater reliability, r: Total: > .85 Walking backwards: .80 Moving sideways: .84 Hopping for height: .96 Jumping sideways: .95 Test-retest reliaiblity: .97	Content validity: Variance of total score by four test items ranged from 81% (age 6) to 98% (age 9) Construct validity: Established using intercorrelations and factor analysis), n = 1228: - Intercorrelations between subtests ranging from WB/JS: .60 to .81 (HH/JS) - Factor analysis: 4 subtests load on same factor - gross motor coordination
FMS: A Manual for Classroom Teachers	Evaluate motor skill proficiency in 11 FMS	Prep - Year 6 (approx. 5-12 years of age)	N	N/A		Y	Limited; Test-retest reliablity: n = 42 (3 boys and 3 girls from Prep to Year 6) Alpha coefficients for each skill ranged from .13-.95: Catch: .92 Overhand throw: .92 Kick: .78 Punt: .86 Forehand strike: .95 Two hand side-arm strike: .90 Ball bounce: .94 Run: .17 Leap: .13 Dodge: .70 Vertical jump: .74	

Tool	Purpose	Age	Normative Data		Assessment Type		Reliability	Validity
			Y/N	Sample	Product	Process		
TGMD-2	Evaluate motor skill proficiency in 12 FMS	3-10	Y	1208 US children in 1997-1998		Y	Inter-rater reliability, r: Across subsets and GMQ: .98 Test-retest reliability, r:, n = 75, 3-10 year olds: Locomotor: .88 Object-control: 93 GMQ: .96 Content sampling, r: Locomotor: .85 Object-control: .88 GMQ: .91	Content description validity: 3 content experts judged whether skills selected are frequently taught in preschool and early primary school Criterion-related validity (correlations between subtests and the Basic Motor Generalizations subtest of the Comprehensive Scales of Student Abilities): Locomotor: .63 Object-control: .41 Composite score: .63 Construct validity: - Age differentiation (correlations with chronological age) - Group differentiation (differentiation between groups of individuals of average, below and above) - Item validity (items correlated with total score of subtests - Subtest correlations (total subtest scores correlate with each other) - Factor analysis (goodness of fit index ranging from .90-.96)

Tool	Purpose	Age	Normative Data		Assessment Type		Reliability	Validity
			Y/N	Sample	Product	Process		
TGMD-3	Evaluate motor skill proficiency in 13 FMS	3-10	Collected - to be published soon			Y	Reliablity testing, n = 807, 3-10.9 years Correlations between average raw scores and age: Total: r = 0.45 Ball skills: r = .47 Locomotor: r = .39 Internal consistency: Cronbach's eoefficient alpha: Locomotor: .95 Ball skills: .95 Total: .97 Test retest reliability, n = 30, 3-10.9 years: Locomotor: .97 Ball skills: .95 Total score: .97	Validity measures, n = 807, 3-10.9 years Item difficulty: range = 0.43-0.91 Item discrimination: range = 0.34-0.67 Construct validity n = 407: Factor analysis: One-factor model (Gross motor skills explaining 73.82% of variance) - factor loadings ranged from .8 (slide) to .9 (kick)
Get Skilled: Get Active	Evaluate motor skill proficiency in 12 FMS	Kindergarten - Year 6 (approx. 5-12 years)	N	N/A		Y	Limited; Test-retest reliability (Grade 1-3 children assessed for different combinations of 6 skills: Mean agreement % scores ranged from 69 for the hop with Grade 1 children to 85% for the kick with Grade 3 children	

2.3 Motor Development

Motor development is the study of changes in movement behaviour across the lifespan, in addition to the processes that influence these changes (Gallahue & Ozmun, 2006). Knowledge of motor development is imperative in order to gain an understanding of overall human development, which involves the interaction of numerous aspects (including social, psychological and cognitive) (Barnett, Stodden et al., 2016). Furthermore, it allows the development of appropriate activities according to one's level of movement abilities, enhancing teaching of movement skills and facilitating further movement development. It also allows for the detection and diagnosis of movement deficiencies and abnormalities that may have negative implications for an individual if not addressed (Payne & Isaacs, 2017). Knowledge of motor development is important for the design of developmentally- and age-appropriate activities to be included in interventions aimed at improving the movement abilities of children.

Numerous theoretical frameworks have been developed to conceptualise and aid the understanding of the dynamic (non-linear) process of motor development, including the development of FMS across the lifespan, such as Gallahue's Triangulated Hourglass Model of Motor Development (Gallahue et al., 2012), as well as Clark and Metcalfe's Mountain of Motor Development Metaphor (Clark & Metcalfe, 2002).

<u>Gallahue and Ozmun's Triangulated Hourglass: A Life Span Model</u>

Gallahue and Ozmun's Triangulated Hourglass: A Life Span Model is a heuristic device (Figure 2.2) incorporating the integration of Gallahue and Ozmun's hourglass model, which provides a description of movement at each specific phase and stage (product), and Newell's Theory of Constraints, which proposes an explanation of motor development (process) (Gallahue et al., 2012).

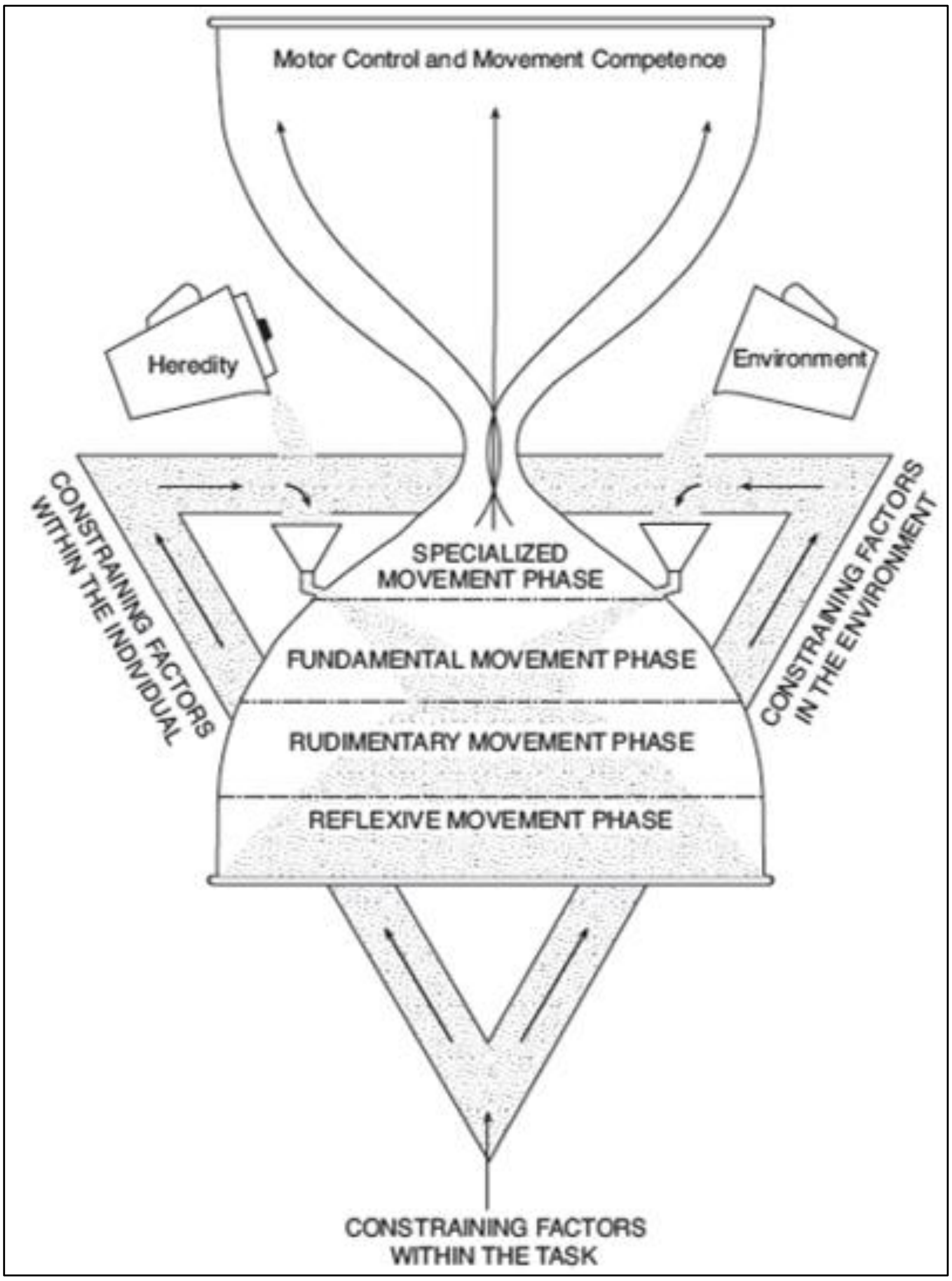

Figure 2.2: Triangulated Hourglass Model: A Life Span Process/Product Model of Motor Development (Gallahue et al., 2012)

In the triangulated hourglass model, motor development is described across four phases, which are further subdivided into stages. The hourglass is filled from the bottom, with what Gallahue et al. (2012) term 'the stuff of life' and referred to as the 'sand' from two different containers: the hereditary container and the environmental container. The hereditary container has 'a lid', a limited or fixed amount of sand while the environmental container has 'no lid' and sand can be added to it and subsequently into the hourglass itself. While movement development occurs in sequential progression through the phases and stages, the age ranges suggested for the various phases of motor development proposed by the hourglass model are regarded as guidelines, as the rate of motor development is variable (Gallahue & Ozmun, 2006).

The first phase of the hourglass model, the reflexive phase is characterized by the first movements made by the foetus and new-born, which are reflexes: involuntary controlled movements which allow the infant to gain information about their surrounding environments. The second phase of the hourglass model is the rudimentary movement phase, encompassing the most basic form of voluntary movements, which are pre-requisite to fundamental movement skills. These movements develop sequentially with maturation to approximately two years of age with rate of development dependent on biological, task and environmental factors. Rudimentary movements include gaining control of the muscles of the head, neck and trunk (stability), reaching, grasping and releasing (manipulative) and crawling and walking (locomotor). This phase involves movements that lack control and refinement but, as a result of rapid neuromotor development, become more controlled and proficient. During the initial two phases of motor development, sand pours into the hourglass primarily from the hereditary container, with some from the environmental container. Beyond the rudimentary phase, as children progress into the fundamental movement skill phase, sand primarily pours from the environmental container, which reflects the suggestion that FMS are not acquired naturally (Gallahue & Ozmun, 2006; Pang & Fong, 2009; Payne & Isaacs, 2002), but rather require quality practice opportunities as well as quality instruction and feedback in order for development to occur (Gallahue et al., 2012; Payne & Isaacs, 2002).

The fundamental movement skill phase is a period where children learn and develop basic, observable patterns of movements involving the combination of one or more body segments. Children begin to develop locomotor (e.g. running, jumping, hopping), manipulative or object-control (catching, throwing, rolling) and stability (e.g. balance) skills. Although maturation does contribute to the development of FMS, they must be learned, practiced and refined in order to become proficient. Quality instruction, practice and feedback are a necessity for the development and acquisition of FMS proficiency (Logan et al., 2011; Smyth & O'Keeffe, 1998). The interaction of task, individual and environmental constraints has a large influence on the development of these skills which are used throughout the lifespan. The fundamental movement skill phase consists of three subphases: Initial Stage, Emerging Elementary Stage and Proficient Stage. The initial stage includes one's first attempts at performing a FMS (approximately 2-3 years of age), which often result in restricted or exaggerated movements of various body segments as well as poor coordination and rhythm. The early elementary stage (approximately 3-5 years of age) represents movements performed with improved control, coordination and rhythm, primarily developed through the process of maturation. The proficient stage is comprised of controlled, coordinated and technically proficient movements. It is through opportunities for quality instruction, practice, encouragement and feedback that children reach this stage. It is understood that the age at which the different stages in the development of motor skills occur, the rate at which FMS develop and the amount of time required to become proficient in skills are highly variable among children (Branta, Haubenstricker, & Seefeldt, 1984). Nonetheless, Gallahue et al. (2012) propose that children have the potential to become proficient in FMS by the age of six. However, there is limited research assessing the relationship between chronological age and the progressive development of FMS. However, some research conducted in the 1980s examined age trends in movement pattern development. Eckert (1973) reported children displayed an 'adult style' walk by the age of four and that of running by the age of five or six. Results also indicated that 43% of children were capable of peforming the gallop by the age of five, with most proficient by 6.5 years. In addition, Gutteridge (1939) who examined a range of skills found that by the age of six, 90% of children were proficient at skipping, 63% were proficient at catching and 74% could throw well. In addition, research by Breckenridge and Vincent (1949) indicated that the majority of children were capable of hopping by this age. Therefore, this existing evidence, although dated, suggests that it may be possible for children to develop proficient performance in FMS by the age of six. However, it is understood that both individual and environmental factors (and the interaction between these factors and the task being performed) influence the rate of development, variability in the rate and age at which children develop FMS is expected (Branta, Haubenstricker, & Seefeldt, 1984). It is also suggested that proficiency in object-control skills may take longer to develop due to the greater visual-motor demands required for these skills e.g. visual tracking and interaction with moving objects (Morgan et al., 2013). When proficiency is achieved, further improvement in these skills may also be made in terms of the product of the movement e.g. throw further, run faster etc.

The acquisition of FMS facilitates progression to the specialized movement phase. This phase is where FMS (locomotor, object-control and stability) are progressed, refined and combined to develop more advanced, sport-specific skills, e.g. the catch and kick can be combined and applied to the games of soccer, rugby and Gaelic football. Progression and success in this stage is dependent on FMS proficiency levels. The specialized movement phase consists of three stages: the transitional stage, application stage and lifelong utilization stage. In the transitional stage, children begin to combine the learned FMS in order to perform sport-specific skills. In the application stage (11 to 13 years of age), children's choice of activity/sports in which to participate, has been found to be influenced by levels of FMS and perceived movement competence (Robinson, Stodden et al., 2015; Stodden et al., 2008). During this stage, particular focus is placed on the accuracy with which skills are executed and skills are refined further for application in a specific sport/activity. The lifelong utilization stage is the final stage, representing the use of the movements and skills acquired throughout all previous phases, including the FMS stage, for use throughout the lifespan. These skills and movements will facilitate and determine the activities and/or sports one can participate in through daily life, recreation and sport. As the sand fills the hourglass, a bell-shape depiction can be envisaged, indicating that while one may be at the proficient stage of one skill e.g. catch, they may be at the initial stage in terms of other skills e.g. hop, i.e. representing the different levels of proficiency across individual FMS and sport-skills.

At some time, the hourglass is upturned and sand begins to fall through two different filters: (i) the hereditary filter, which one has no control of and from which once sand has fallen from cannot be regained, e.g. predisposition to medical condition and (ii) the lifestyle filter, of which the porosity is influenced by things such as exercise, diet, well-being and stress. However, sand can still be added through further motor development (FMS and sport-specific skills) achieved through practice opportunities (and also instruction and feedback, where possible by coaches or significant others), facilitated through the physical activity one engages in.

Throughout the various stages and phases, Newell's Theory of Constraints (Newell, 1989) proposes that movements are also influenced by the interaction of (i) the individual, (ii) the task being attempted and (iii) the environment in which the movement occurs. These three variables or factors are referred to as 'constraints', which are factors which may either limit or encourage movement (Haywood & Getchell, 2009):

- Individual constraints – may be either structural or functional. Structural constraints refer to physical characteristics and include height, body mass and flexibility. Functional constraints refer to behavioural or mental characteristics and include motivation, attention and fear.
- Environmental constraints – may be physical or sociocultural. Physical environmental constraints refer to characteristics such as weather, terrain, light etc. Examples of sociocultural constraints include socioeconomic status, preferences for particular types of sports (e.g. boys tendency to engage more in ball sports).
- Task constraints – refer to the goal of the movement and include characteristics which are task-specific. These include the desired outcome (e.g. to score a goal in soccer, a player must get the ball in the net), the rules surrounding the task (e.g. a player can only score by kicking or heading the ball; a player cannot handle the ball while in play), the equipment used (including size, shape, type).

With changes in any of these constraints (i.e. individual, task or environment), the resultant movement can change (Haywood & Getchell, 2009). For example, it may not be possible for a young child to attempt to hit a tennis ball over a tennis net of standard height using a standard sized racket due to individual constraints (body height and strength). It may be necessary to reduce the racket size and weight, use a lighter weighted tennis ball and reduce the height of the net (i.e. modify task and environmental constraints) to encourage and facilitate movement. It is the patterns of the interaction of the individual, task and environmental constraints over time which contribute to changes in motor development.

Clark and Metcalfe's Mountain of Motor Development Metaphor

Another such theoretical framework, Clark and Metcalfe's mountain of motor development metaphor (Clark & Metcalfe, 2002) relates motor development to climbing a mountain and related attempts to reach the top level (mountain peak/skilfulness). Progress, the rate of which is variable for each individual and across different stages, occurs in sequence across time. Similar to the model proposed by Gallahue et al. (2012), progress will be either be facilitated or hindered depending on the interaction of the individual, task and the environment (Newell, 1986).

A comparison of both models by Salehi, Sheikh, & Talebrokni (2017) identified similarities and differences between both proposed theories, which are displayed in Table 2.5. In contrast to the four phases of development in the hourglass model, Clark and Metcalfe's metaphor proposes six developmental periods: reflexive, preadapted, fundamental patterns, context-specific, skilfulness and compensation. The initial phases (reflexive period/phase) of both models largely overlap in the concepts proposed. The second phase of both models, the preadapted period (mountain of motor development metaphor) and the rudimentary phase (hourglass model), present similar characteristics; however, some differences exist. In the hourglass model, the rudimentary phase consists of movements that are categorised into one of three categories: locomotor, manipulative or stability movements (which outline the movement categories in which FMS are also categorised). In contrast, while describing similar movements required for infant survival (i.e. locomotion and feeding), movements are not specifically categorised until the fundamental movement skill phase in the mountain of motor development metaphor.

The fundamental movement skill phase (hourglass model) and the fundamental patterns period (mountain metaphor) describe and explain similar concepts, with one apparent difference. Both theorize that lack of opportunities (practice, instruction, feedback, physical space etc.) increase the difficulty in becoming proficient in FMS, thus restricting their ability to further develop and apply these skills in physical activity and sport. In the hourglass model (Gallahue et al., 2012) lack of FMS competence is referred to as a 'proficiency barrier'. In contrast, Clark and Metcalfe (2002) refer to one's FMS proficiency level as the 'basecamp' of the mountain, from which one attempts to climb, through FMS and sport-specific skill development, toward skilfulness. The context-specific and skilfulness periods of Clark and Metcalfe's mountain of motor development are largely compatible with the stages (transitional, application and life utilization phase) of the specialised movement phase in the hourglass model. The final period of the mountain metaphor, compensation, is proposed to occur through two possible avenues: injury or declination with age from middle to late adulthood. However, with continued skills training and learning (FMS and sport-specific skills) as well as through physical activity, the effects of ageing (of which some are inevitable) may be slowed and/or delayed. This period is similar to the turning over of the hourglass in the model of motor development proposed by Gallahue and colleagues (2012). Similar to the bell-shape curve representing variable proficiency levels across the skills of the hourglass model, Clark and Metcalfe (2002) compare the variable proficiency levels across skills to climbing various peaks within the mountain range, suggesting that while one may be skilled in the tennis serve (high peak), may lack proficiency in the rugby pass (low peak or flat terrain).

Table 2.5: How Mountain of Motor Development (Clark & Metcalfe, 2002) differs from the Triangulated Hourglass Model of Motor Development (Gallahue et al., 2012)

Period of Development in the Mountain of Motor Development	How it is similar to the Hourglass Model	How it differs from the Hourglass Model
Overall Model	Describes and conceptualises motor development from both a process and product perspective	Consists of 6 phases: 1. Reflexive 2. Preadapted 3. Fundamental patterns 4. Context-specific 5. Skilfulness 6. Compensation
Reflexive	Similar to Reflexive Phase	
Preadapted	Simliar to Rudimentary Phase	The movements described in this period are not categorised as is the case in the rudimentary phase of the hourglass model with movements categorised into one of 3 categories (locomotor, manipulative or stability)
Fundamental Patterns	Similar to Fundamental Movement Phase	One's FMS competence is referred to as the 'basecamp' of the mountain, from which one attempts to climb towards skilfulness; in contrast to the hourglass model which refers to one's lack of competency as a 'proficiency barrier'
Context-Specific Skilfulness	Similar to Specialised Movement Phase	Two phases (Context-Specific and Skilfulness) are used to describe concepts described within one phase (Specialised Movement Phase) of the hourglass model
Compensation	Similar to upturning of hourglass model	Variable proficiency levels across skills are compared to peaks of various heights within a mountain range; in contrast to a bell-shaped curve representing variable proficiency levels in the hourglass model

Both models, incorporating the interaction of individual, task and environmental constraints (Newell, 1986), describe and conceptualise motor development (from both a process and product perspective) and emphasise the importance of fundamental movement skills in this development. While the initial two stages of both models primarily occur through natural maturation, movements described and proposed to develop during the fundamental movement skill phase/fundamental patterns period must be learned, practiced and reinforced. Without quality teaching of skills, practice attempts undertaken by the individual as well as quality feedback received, children will experience a ‘proficiency barrier’ as described by Gallahue et al. (2012) and will not progress from the ‘basecamp’ as described by Clark and Metcalfe (2002). Movements learned during the fundamental movement skill phase/fundamental patterns period form the foundation upon which more complex sport-specific skills are based. Thus, this phase/period is critical for motor development in children.

2.4 FMS and Associated Health Benefits

The ability to perform FMS correctly (i.e. FMS proficiency/mastery) is associated with numerous health benefits and is important for the holistic development of children; including physical, psychological, social and overall well-being (Barnett, Stodden et al., 2016). Several recent systematic reviews investigating the relationship between motor competence and associated health benefits among children and youth have reported that FMS proficiency is positively associated with higher levels of PA (Holfelder & Schott, 2014), physical fitness (Cattuzzo et al., 2016) and inversely associated with weight status (Cattuzzo et al., 2016; Lubans et al., 2010). It has also been shown to be associated with greater cognitive functioning and academic performance (Haapala, 2013). Furthermore, longitudinal evidence reveals that FMS proficiency tracks through childhood (Branta, Haubenstricker, & Seefeldt, 1984; Malina, 1990) into adolescence (Barnett et al., 2010; McKenzie et al., 2002) and is a significant predictor of adolescent PA (Barnett, et al., 2009). Some studies, on the other hand, have found no significant associations between FMS and markers of health. Both Hume et al. (2008) and Castelli and Valley (2007) found that FMS was not associated with BMI z-scores among children. Similarly, while McKenzie et al. (2002) found an inverse relationship between FMS and adiposity among boys, no association was found among girls. Furthermore, McKenzie and colleagues (2002) also revealed that FMS proficiency at 4-6 years of age did not predict PA levels at 12 years of age. Based on existing research, the majority of which has reported positive findings, evidence suggests a positive association between FMS and markers of health (Robinson, Stodden et al., 2015).

2.4.1 FMS and Health-Related Variables

A conceptual model developed by Stodden et al. (2008) hypothesises the existence of associations among motor competence (including FMS), physical activity, perceived movement competence, health-related physical fitness and obesity.

Conceptual Model

In the model of Stodden et al. (2008) and the updated commentary by Robinson, Stodden et al. (2015) on the evidence supporting the model, motor competence (MC) is the term used to describe goal-directed human movement which has been used interchangeably in previous literature with the following: fundamental movement/motor skills, motor proficiency, motor performance, motor ability and motor coordination. For the purpose of the current research, the term FMS will be used to describe what is referred to in the models as 'motor competence'.

It was proposed by Stodden et al. (2008), that the development of FMS is a 'fundamental' or core mechanism that enables and encourages physical activity participation. Failure to become proficient in FMS will prevent the development of more sport-specific skills and thereby limit opportunities for physical activities and games throughout childhood and adolescence. Stodden and colleagues (2008) developed a conceptual model, which was based on previous theoretical models (Clark & Metcalfe, 2002; Seefeldt, 1980), to demonstrate how different factors may interact (across developmental time) to influence participation in physical activity. This model proposed existing relationships between FMS and physical activity as well as perceived motor skill competence, health related physical fitness and weight status. Since 2008, much research has been conducted investigating these relationships and hypotheses. The evidence found has been used in the examination of the proposed associations of the conceptual model and reported by Robinson, Stodden et al. (2015).

Central to Stodden's model (2008) is the concept that there is a dynamic and reciprocal relationship between FMS and PA, which strengthens as children develop. Higher levels of physical activity promote greater opportunities for practice and mastery attempts, which further promotes the development of FMS (Fisher et al., 2005; Okely, Booth, & Patterson, 2001a). During the pre-school years (2-5 years), the physical activity levels of young children is quite variable and is dependent on a number of influencing factors including environment, parents, PE delivered in school, outside school activities available, facilities etc., (DiLorenzo, Stucky-Ropp, Vander Wal, & Gotham, 1998; Goodway & Smith, 2005; Sallis, Prochaska, & Taylor, 2000). Therefore, a weak relationship is expected between FMS and PA. However, as children progress through the primary school years, it is hypothesised that this relationship strengthens, as those with greater FMS proficiency will have the ability to participate in a wide range of activities/sports and thus, engage in high levels of PA which will facilitate further development of these skills. On the contrary, those with lower FMS proficiency will demonstrate lower PA levels, providing limited opportunities for FMS development.

Perceived motor or movement competence (PC), or one's perception of his her movement ability, is proposed as a mediator of the relationship between FMS and PA. In early childhood, children exhibit limited cognitive ability and fail to distinguish between actual competence, effort and practice time and attempts (Harter, 1999). Thus, inflated levels of perceived competence and little or weak association with actual competence or PA is expected among young children (under seven years). With age and cognitive development, children become capable of forming more accurate perceptions of their ability (Harter, 1978, 1999; Piaget, 1959). As a result, the association between PC and actual motor competence is proposed to increase. It is suggested that those with low FMS proficiency will exhibit low PC, as they begin to acknowledge their lack of proficiency in comparison to others and as a result participate in low levels of PA (Rudisill, Mahar, & Meaney, 1993; Weiss & Amorose, 2005). On the contrary, those with higher levels of FMS proficiency will exhibit higher levels of PC, as they become aware of successful attempts when performing skills, increasing motivation to engage in PA involving these skills (Rudisill et al., 1993; Weiss & Amorose, 2005).

The relationship between FMS and health-related fitness (HRF) is suggested to be weak in early childhood due to the expected variable levels of FMS at a young age, but increase in strength across developmental age (Cattuzzo et al., 2016; Stodden et al., 2008). As children progress into middle and late childhood (8-13 years), it is proposed that those with greater FMS proficiency who engage in higher levels of PA, will demonstrate greater health related fitness. This will further increase participation in activities requiring high levels of PA (and FMS proficiency), promoting continued FMS development. In contrast, those with low FMS and consequently lower PA levels will have lower health-related fitness, restricting their PA opportunities to activities requiring low levels of PA (and FMS proficiency) and consequently preventing the development FMS and HRF. For this reason, HRF is suggested to play a mediating role between FMS and PA (Stodden et al., 2008), an association which has received limited investigation.

Weight status is the final component of the conceptual model with which there is an expected reciprocal and dynamic relationship with the other components of the model (i.e. MC, PC, PA and HRF) (Stodden et al., 2008). Overweight/obese children have been found to encounter increased difficulty with locomotion and movement compared to their non-overweight peers (Slotte, Saakslahti, Metsaemuuronen, & Rintala, 2015) as a result of the requirement to move their greater body mass (Riddiford-Harland, Steele, & Storlien, 2000; Siahkouhian, Mahmoodi, & Salehi, 2011). Consequently, it is suggested that these children exhibit poorer FMS levels (especially locomotor skills) and thus, based on the aforementioned proposed associations of the model, they may also exhibit low PC, PA and be less likely to engage in PA and HRF. Therefore, it is proposed that the interaction of the other components within the model plays an influential role on the weight status of an individual, while weight status may also play an important mediating role in each of the relationships within the model (Stodden et al., 2008).

Considering the interaction of all concepts within the model, it is proposed that over a period of time, children may be drawn into what is referred to as either a ‘positive spiral of engagement’ or ‘negative spiral of disengagement’ (Stodden et al., 2008). A positive spiral of engagement results from the interaction of higher levels of motor competence, perceived motor competence, PA levels, health related fitness which promote a favourable health status. On the contrary, a negative spiral of disengagement culminates from the interaction of low levels of motor competence, perceived motor competence, poor health related fitness, high levels of physical inactivity and obesity. In the developmental conceptual model (Stodden et al., 2008), which has been supported in the research (Robinson, Stodden et al., 2015) (Figure 2.3), FMS or actual motor competence is regarded as one of the most essential factors influencing participation in PA.

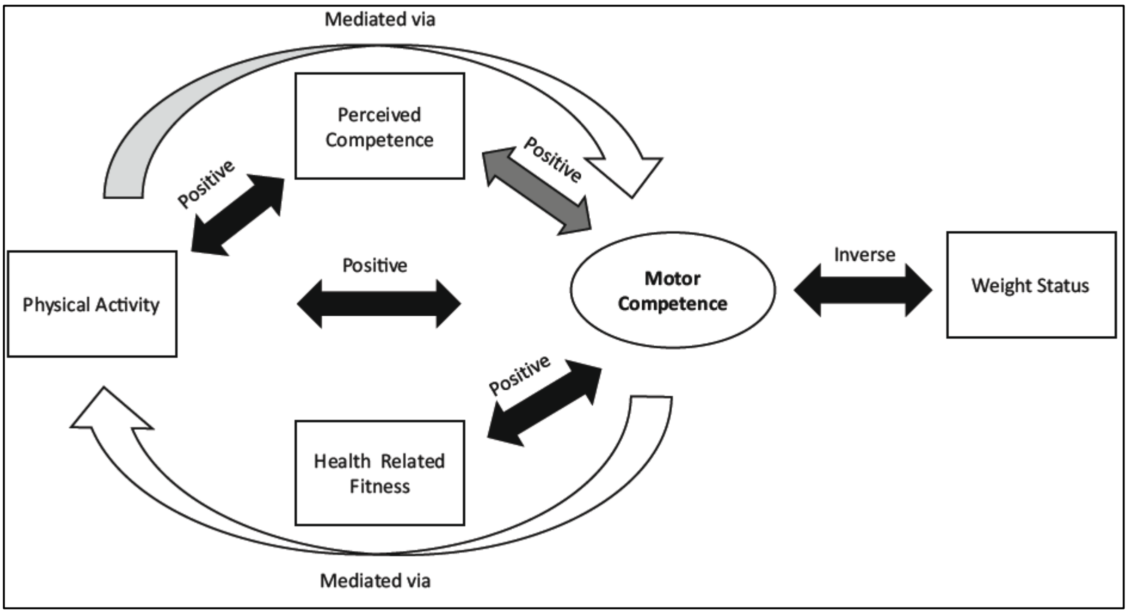

Figure 2.3: Research consensus on motor competence and health-related variables. Black arrow indicates extensively tested: consistent relationship; dark grey arrow indicates moderately tested: variable relationship; partial grey arrow indicates partially tested: some evidence; white arrow indicates limited testing. The direction of the relationship is indicated above the arrows (Robinson, Stodden et al., 2015)

FMS and PA

Since the proposal of Stodden's conceptual model, the relationship between MC and PA has been extensively investigated and a consistent positive relationship has been reported to exist among these variables (Robinson, Stodden et al., 2015). A systematic review by Lubans et al. (2010) included 13 studies that examined the relationship between FMS (assessed using both product- and process-oriented assessment tools) and PA among children and adolescents, of which 12 reported the existence of a positive association. However, the strength of associations were not included. Similar findings were reported in a review by Logan et al. (2011) with 12 of 13 articles examining the association of FMS (assessed using only process-oriented measurements) and PA, providing further evidence for the positive correlation between variables (r = .16 to r = .55; small to large correlations). Likewise, a review conducted by Holfelder & Schott

(2014) found a positive correlation between motor competence and PA in 12 of 23 studies (*r* = .10 to *r* = .92; small to large correlations), which included measures of motor abilities, motor coordination as well as FMS.

Furthermore, longitudinal evidence supports the existence of an association between childhood FMS proficiency and adolescent PA levels (Barnett et al., 2009; Lopes, Stodden, Bianchi, Maia, & Rodrigues, 2012). It was found that 6-year-old children with high levels of FMS had maintained their PA levels three years later, in comparison to those with lower FMS among whom a decline in PA levels was observed (Lopes et al., 2012). Also, Barnett et al. (2009) found that childhood object-control proficiency accounted for 3.6% of time spent in MVPA and 18.2% of time spent in organised sport during adolescence. However, childhood locomotor proficiency was not associated with PA in adolescence. A limitation of both longitudinal studies was that PA was assessed via self-report measures, as opposed to objective measures (e.g. via accelerometry). Therefore, while evidence suggests a positive association between childhood FMS and PA levels during adolescence, due to the limited longitudinal research conducted, further research and evidence is required to provide greater support for these findings.

Perceived Competence and its Role in the Relationship between FMS and PA

In the research consensus model by Robinson, Stodden et al. (2015) (Figure 2.3), it is reported that the direct relationship between FMS and PC has been moderately tested with investigations producing variable findings while a consistent relationship has been reported between PC and PA following extensive testing (Robinson, Stodden et al., 2015; Stodden et al., 2008). There is also some existing evidence supporting the mediating effect of PC on the relationship between MC and PA (Robinson, Stodden et al., 2015; Stodden et al., 2008), but requires further testing. A limitation of previous research investigating the association between actual and perceived movement competence is the use of assessment tools that do not include the same skills (i.e. the tools are not aligned), an essential requirement if an accurate evaluation is to be obtained (Barnett, Ridgers, Zask, & Salmon, 2015; Liong, Ridgers, & Barnett, 2015). Previous studies using unaligned measurement tools have reported the existence of a positive relationship between actual FMS and PC among pre-school aged children (LeGear et al., 2012;

Robinson, 2011) and a cohort of 6- to 7-year-olds (Toftegaard-Stoeckel, Groenfeldt, & Andersen, 2010), while others have found no associations among 4- to 7-year-olds (Spessato, Gabbard, Robinson, & Valentini, 2013).

In recent years, the development of the Pictorial Scale of Perceived Movement Skill Competence for Young Children (PMSC) (Barnett, Ridgers, Zask et al., 2015), which assesses one's PC in performing each of the 12 FMS included in the TGMD-2, has enabled the use of aligned measurement tools in the investigation of the relationship between actual and perceived movement competence. Using these aligned tools, positive (although weak) correlations between perceived and actual object-control competence among cohorts of 4- to 8-year-old children (Barnett, Ridgers, & Salmon, 2015) and 5- to 8-year-old boys (Liong et al., 2015) have been reported. However, no significant relationship was found between perceived and actual locomotor or total FMS competence by Liong et al. (2015). Similarly, among 9 to 11-year-olds, Barnett, Salmon, Timperio, Lubans, and Ridgers (2017) found no significant association when comparing perceived and actual competence in locomotor, object-control or total FMS skills. Due to the limited research conducted investigating this relationship using aligned measurement tools, further research is warranted to ascertain the existence (and strength, if found) of the relationship between actual and perceived FMS competence.

The relationship between PC and PA has also been extensively examined. In a recent systematic review and meta-analysis, a consistent positive association between perceived competence (operationally defined as one's assessment of their ability to perform sports and recreational activities) and PA among youth was reported (Babic et al., 2014). A qualitative review of the studies relating to PC (as other aspects of self-concept were also included in this review) revealed a significant association between PC and PA in 24 of the 29 (83%) relevant studies. Results from the meta-analysis, which included 59 studies, revealed a moderate association (r = .33) between PC and PA. Age was also found as a significant moderator of this relationship, with weak associations found among children (r = .08) and moderate associations found among early and late adolescents (r = .31 - .35). The weaker association among children compared with adolescents provides support for the proposal that children's ability to accurately perceived their ability increases with cognitive development as children age (Babic et al., 2014).

It must be noted, however, that few studies have investigated the relationship between perceived competence in performing FMS and their PA levels (Barnett et al., 2017; Barnett, Ridgers, & Salmon, 2015; Barnett, Salmon, & Hesketh, 2016; Slykerman, Ridgers, Stevenson, & Barnett, 2016). Barnett et al. (2017) found no significant relationship between perceived FMS competence and moderate-to-vigorous physical activity (MVPA) levels among 9- to 11-year-olds, nor with perceived object-control competence among 4- to 8-year-old Australian children (Barnett, Ridgers, & Salmon, 2015). Similarly, Slykerman et al. (2016) found perceived skill scores were not significant predictors of MVPA among 5- to 8-year-old Australian children. In contrast, a longitudinal study by Barnett, Salmon et al. (2016) revealed that time spent in MVPA at 3.5 years predicted perceived FMS competence at five years of age, despite cross-sectional analysis at five years revealing no associations. With the recent development of the PMSC, future and further studies assessing this relationship is possible and expected providing more insight into the association between FMS, PC and PA. Based on the existing research and proposed associations between FMS, PC and PA, interventions aimed at improving actual FMS and PA levels among children should incorporate activities and strategies to increase children's perceived movement competence, which may promote FMS development and increase PA levels.

<u>FMS and Cardiorespiratory Fitness</u>

There is much evidence supporting the direct relationship between motor competence and cardiorespiratory fitness (CRF). In a recent systematic review by Cattuzzo et al. (2016), all 16 studies which examined the relationship between FMS (using a range of both process- and product-oriented motor competence tool) and CRF (either independently or as part of a health-related fitness test battery) reported positive associations, with medium to large correlations found (r =.32 to r = .57). In addition, Lubans et al. (2010) in an earlier review, also reported a positive association in all of the 4 relevant studies, which investigated the relationship between motor competence and CRF among children and adolescents. Three of the four studies used a process-oriented assessment tool to assess FMS proficiency, including the TGMD (Marshall & Bouffard, 1997), Get Skilled: Get Active (Barnett, van Beurden et al., 2008) and the Department of Victoria Manual for Classroom Teachers (Okely, Booth, & Patterson, 2001b), while one study used a product-oriented tool, the BOTMP (Reeves, Broeder, Kennedy-Honeycutt, East, & Matney, 1999). Three of the four studies used the multi-stage fitness test as a measure of CRF (Barnett, van Beurden et al., 2008; Marshall & Bouffard, 1997; Okely et al., 2001b), while in the fourth study, a half mile walk test was used (Reeves et al., 1999). Moderate correlations were found between measures of FMS and PA in the studies of Marshall and Bouffard (1997) (r = .37 - .48 for different TGMD subsets), Reeves et al. (1999) (r = .32- .40 for different subsections of the KTK) and Okely et al. (2001b) (r = .33 - .50 across different groups based on age and sex). Furthermore, in the study of Barnett, van Beurden et al. (2008), it was found that childhood object-control proficiency was found to account for 26% of the variance in adolescent CRF. Evidence from these reviews and studies provide strong support for the existence of a direct relationship between motor competence and CRF among children and adolescents.

<u>FMS and Weight Status</u>

The relationship between FMS and weight status has been extensively examined and consistent findings have been reported, indicating an inverse association between FMS and weight status among children and adolescents (Cattuzzo et al., 2016; Lubans et al., 2010; Robinson, Stodden et al., 2015). In the review of Cattuzzo et al. (2016), 27 of 33 studies (82%) provide strong support for the existence of the inverse relationship between FMS proficiency and weight status among children and adolescents. In the remaining six studies, five of which were identified as high risk of bias, no relationship was found between variables. Similar findings are reported by Lubans et al. (2010) in a systematic review of the associated health benefits of FMS in children and adolescents. Of eight relevant studies, five reported a significant inverse relationship between FMS and weight status. Various methodologies were used in the assessment of both motor competence/FMS, including the KTK (Graf et al., 2004), TGMD-2 (Southall, Okely, & Steele, 2004), MAB-C (D'Hondt, Deforche, De Bourdeaudhuij, & Lenoir, 2009), FMS: A Manual for Classroom Teachers (Hume et al., 2008; Okely, Booth, & Chey, 2004), the South Carolina Physical Education Assessment Program (SCPEAP) (Castelli & Valley,

2007) and CHAMPS Motor Skill Protocol (CMSP) (Williams et al., 2008) as well as weight status, including BMI (D'Hondt et al., 2009), BMI z-scores (Castelli & Valley, 2007; Graf et al., 2004; Hume et al., 2008; Okely et al., 2004; Southall et al., 2004; Williams et al., 2008) and skinfolds (McKenzie et al., 2002). Weak inverse associations were found by both McKenzie et al. (2002) (r = -.22; boys only) and Graf et al. (2004) (r = -.16). In the study by Okely et al. (2004), BMI (and waist circumference) were found to be significant predictors (r = .10-.32) of FMS proficiency while D'Hondt et al. (2009) found BMI z-scores accounted for 11.8% of total MAB-C score (as well as 20% of the static and dynamic subset score and 3.9% of ball skills score). In addition, Southall et al. (2004), reported significantly greater total (p = .29) and locomotor standard scores (p = .46) among non-overweight children in comparison to their overweight/obese peers. Therefore, the majority of research investigating the association between FMS and weight status have provided evidence supporting the existence of an inverse relationship between these variables among children and adolescents.

Childhood Obesity

At present, childhood obesity and physical inactivity are major health concerns worldwide (World Health Organization [WHO], 2018a, 2018c). While these problems have been identified as multifaceted, in recent times much research has focused on FMS and their association with numerous markers of health. In light of positive findings (Barnett, Stodden et al., 2016; Lubans et al., 2010), this area is being explored as a possible avenue or mechanism through which to combat this global crisis that exists in the 21st century. It is estimated that approximately 10% of school-aged children (5-17 years) worldwide are overweight or obese, with figures in Europe and North America as high as 20% and 30%, respectively (Ahmad, Ahmad, & Ahmad, 2010). Children who are overweight or obese are likely to remain overweight or obese throughout their lifespan and have an increased risk of developing numerous chronic diseases such as hypertension, type 2 diabetes, heart disease, stroke and certain cancers among many other non-communicable diseases (Raj & Kumar, 2010; World Health Organization [WHO], 2018b). Childhood obesity has long-term consequences on mortality and morbidity (Raj & Kumar, 2010), with obesity accounting for over 2.8 million deaths annually (World Health Organization, 2018g). Furthermore, obesity is a global economic burden (Tremmel, Gerdtham, Nilsson, & Sanjib, 2017), which is ever increasing among children (WHO, 2018g). Strong evidence indicates the existence of an inverse relationship between FMS and weight status, with those with greater FMS proficiency exhibiting a healthier weight status than those with poor FMS levels. Interventions aimed at improving both FMS and body composition concurrently are suggested to improve the status of both.

Worldwide Physical Inactivity

Physical inactivity, among children, adolescents and adults, is a current global concern, regarded as a pandemic resulting in extensive health, economic and social implications (Ding et al., 2016; Kohl et al., 2012). It is reported that 31% of the world's population fail to reach the daily WHO Physical Activity Guidelines, with 35% of the European population classified as physically inactive (Hallal et al., 2012). In recent times, the development and publication of the Report Card on Physical Activity for Children and Youth has made the evaluation and comparison of the physical activity status of children and youth across countries possible. The Report Card uses an international grading score system ranging from A (highest grade) through to F (lowest grade) to evaluate different aspects of physical activity within a country (Colley, Brownrigg, & Tremblay, 2012). A comparison of the Report Cards from 38 countries across six continents revealed that worldwide levels of physical activity among children and youth are poor, achieving an average grade of 'D' (poor), indicating <40% are physically active, with 74% of countries (including all European countries in the study and the United States) receiving a D grade or lower (Tremblay et al., 2016). In Ireland, the 2016 Report Card revealed poor overall physical activity among children and youth (D-Grade) (Research Work Group for Ireland's Report Card on Physical Activity in Children and Youth, 2016), showing little improvement from 2014 (Grade of D-) (Harrington et al., 2014). Reported as the fourth leading cause of mortality worldwide (Ekelund, 2018), physical inactivity has been attributed to 6-10% of non-communicable diseases worldwide (Lee et al., 2012), in excess of five million deaths annually (Ekelund, 2018).

Recent systematic reviews provides evidence of a consistent association between PA levels and FMS proficiency among children and adolescents, indicating that those with greater FMS levels tend to participate in higher levels of PA. Therefore, strategies to improve FMS proficiency levels, which have been shown to be low worldwide, have the potential to positively influence PA levels among youth. Appropriate physical activity is essential as it helps develop healthy cardiovascular and musculoskeletal systems, helps maintain a favourable weight status and psychological well-being and aids in the prevention of many health disorders and diseases that contribute to early morbidity and mortality (Ding et al., 2016). Thus, effective interventions aimed at improving FMS and PA concurrently, both short and long-term, are required to combat this physical inactivity crisis that is exerting a substantial economic burden with costs on global health care systems exceeding 50 billion in 2013 (Andersen, Mota, & Di Pietro, 2016).

In the attempt to improve the current health and physical activity status of children worldwide, the WHO has devised a Global Strategy on Diet, Physical Activity and Health (DPAS) (Waxman & World Health Assembly, 2004) with improving physical activity highlighted as a main areas of focus. As a result, various avenues and correlates of physical activity, including FMS, have been and continue to be explored in the research as possible mechanisms or pathways that may facilitate these improvements in physical activity levels and health.

2.5 FMS Proficiency Levels

The following section provides an overview of (i) age- and sex-related differences in FMS proficiency among children, (ii) environmental factors influencing FMS proficiency levels, as well as the current FMS proficiency levels in Ireland. A systematic review of the current FMS proficiency levels among primary school aged children worldwide, assessed using the Test of Gross Motor Development-2 (Ulrich, 2000) is presented in Chapter 4.

Age-related Differences

Age has been found to influence the FMS proficiency levels of children (Bardid et al., 2016; Bryant et al., 2014; Freitas et al., 2015; Spessato, Gabbard, Valentini et al., 2013; Booth et al., 2006), with older children typically exhibiting superior FMS proficiency than their younger counterparts (Bardid et al., 2016; Freitas et al., 2015; Mitchell et al., 2013; Spessato, Gabbard, Valentini et al., 2013). In a study of Year 4 (aged 8-9 years) and Year 5 (aged 9-10 years) children in central England, the older cohort performed significantly greater than the younger group in all 8 skills assessed, except the kick (Bryant et al., 2014). Similarly, among 3- to 10-year-old Brazilian children (*n*=1248) and 3- to 8-year-old Belgian children (*n*=1614), a significant age effect was reported for both locomotor and object-control proficiency. Bardid et al. (2016) found that in the locomotor subset, the 4-, 5- and 6-year-old children scored significantly greater than the year group below them, while in the object-control subset, all individual age groups (ranging from 4-8 years) performed significantly better than the year group below them (Bardid et al., 2016). Likewise, among 7- to 10-year-old Portuguese children, Freitas et al. (2015), revealed both locomotor and object-control subset scores significantly increased with age. It is proposed that the increase in FMS proficiency with age is due to the process of natural maturation and additional instruction, practice and feedback (Charlesworth, 2016).

Sex-related Differences

Sex has also been found to be a known determinant of FMS proficiency levels among children. Boys have commonly been found to demonstrate higher levels of overall FMS compared to girls (Barnett, van Beurden et al., 2008; Charlesworth, 2016; Slykerman et al., 2016; Spessato, Gabbard, Valentini et al., 2013). In 2013, Spessato and colleagues assessed the proficiency of 1248 children aged 3 to 10 years using the TGMD-2, with results revealing boys had significantly greater object-control proficiency (across all ages) as well as locomotor proficiency (among 7 to 10-year-olds). Similarly, Slykerman et al. (2016) reported higher FMS proficiency (both locomotor and object-control subsets) among boys in comparison to girls, among a cohort of 5- to 8-year-old Australian children who completed the TGMD-2.

In several other studies, however, no sex-related differences were found within overall FMS performance (Hardy, King, Farrell, Macniven, & Howlett, 2010; Kordi et al., 2012). In a study conducted by Hardy, King, Farrell, et al. (2010), among 425 Australian pre-school children, it was reported that no significant difference was found for total FMS score (TGMD-2) between boys and girls. Similarly, among a cohort of pre-school children in Iran (*n*=147) (Kordi et al., 2012) and 6-year-olds in Indonesia (Bakhtiar, 2014), examined using the TGMD-2 assessment tool, no significant differences were found between the proficiency of boys and girls for either locomotor or object-control subset scores. These findings may suggest sex-related FMS differences emerge as children age and progress through the primary school years. Thus, this highlights the importance of equal encouragement, instruction and practice opportunities for both boys and girls to develop FMS, especially object-control skills during childhood (Spessato, Gabbard, Valentini et al., 2013).

Sex differences in FMS proficiency have predominantly been explained by the type of activities that children undertake, with boys and girls possessing very similar biological characteristics such as genotype, body composition, strength and limb length prior to puberty (Malina, Bouchard, & Bar-Or, 2004). These activities that boys and girls engage in are largely influenced by social and environmental factors such as the influence of family, peers, teachers and the physical environment (Booth et al., 1999; Hardy, King, Farrell, et al., 2010; Thomas & French, 1985), with boys participating more in ball sports (object-control related activities) while girls participate more in dance and gymnastics (locomotor related activities) (Bardid et al., 2016; Booth et al., 1999, 2006; Hardy, King, Farrell, et al., 2010).

Therefore, it is not surprising that many studies have found that boys have greater object-control proficiency (Bardid et al., 2016; Booth et al., 2006; Hardy, King, Farrell, et al., 2010; Lubans et al., 2010; Spessato, Gabbard, Valentini et al., 2013; van Beurden, Barnett, & Dietrich, 2002; Slykerman et al., 2016) than girls, with few reporting no sex-related differences in object-control proficiency (Bakhtiar, 2014; Kordi et al., 2012; van Beurden et al., 2002) among children. Among 3- to 8-year-old Belgian children (Bardid et al., 2016) and 3- to 10-year-old Brazilian children (Spessato, Gabbard, Valentini et al., 2013), boys were found to have a significantly higher object-control subset score than girls at each individual age. Similarly, the 2004 NSW SPANS (Schools Physical Activity and Nutrition Survey) reported that in the three object-control FMS assessed using process-oriented checklists, boys had significantly greater proficiency in each (kick, throw and catch) among Year 2-10 children (7-16 years) (Booth et al., 2006). These findings are further supported by a study of pre-school children from Australia in which boys were found to have higher total and individual object-control scores (strike, catch, kick and throw) in comparison to girls, with the exception of the catch (Hardy, King, Farrell, et al., 2010). A similar trend was found by Bakhtiar (2014) among 6-year-old children from Indonesia and Kordi et al. (2012) among pre-school children from Iran, with object-control subset scores found to be higher among boys than girls, although these differences were not found to be significant.

In relation to locomotor skill proficiency, mixed findings have been reported, with some research reporting no sex-related differences (Bardid et al., 2017; Bakhtiar, 2014; Barnett, van Beurden et al., 2008; Kordi et al., 2012; van Beurden et al., 2002), while others have found that girls perform significantly better than boys at these skills (Barnett et al., 2009; Hardy, King, Farrell, et al., 2010). In recent studies, no significant sex-related differences in locomotor subset scores were found among 1614 children in Belgium (aged 3-8 years) (Bardid et al., 2016), 6-year-old Indonesian children (Bakhtiar, 2014) and among pre-school Iranian children (mean age: 4.95) (Kordi et al., 2012). In contrast, in Australia, among a cohort of 8- to 10-year-old primary school aged children, girls were found to be more proficient at locomotor skills than their male counterparts, assessed using the 'Get Skilled: Get Active' resource (Barnett et al., 2009), as well as among 4- to 5-year-old pre-school children (Hardy, King, Farrell, et al., 2010). The greater locomotor proficiency among girls has been previously accounted for by the types of activities that girls are more likely to participate in such as dance, athletics and gymnastics; all of which have a significant emphasis on locomotor skills (Booth et al., 1999, 2006). However, similar levels of locomotor proficiency demonstrated by both boys and girls may result due to the incorporation of locomotor skills (e.g. running, hopping, jumping) in many of the sports and activities which boys tend to participate in (i.e. team, ball and evasion sports). For example, while soccer involves skills such as kicking, passing and dribbling a soccer ball (skills requiring the manipulation of an object), the ability to run, jump and dodge (among other locomotor skills) are also required, thus providing practice opportunities to develop these locomotor skills.

To bridge any sex-related differences that exist, most notably those in object-control proficiency, it is important that both boys and girls are encouraged, instruction and provided with opportunities to practice all skills during PE, extra-curricular activities and free play (Spessato, Gabbard, Valentini et al., 2013). It is also important to consider how boys and girls interactions differ when they are learning FMS. Garcia (1994) found that girls interacted in a cooperative, caring, sharing manner while boys interacted in a competitive, individualised, and egocentric manner. Given these tendencies, FMS interventions should include developmental activities that involve team work and cooperative learning opportunities to enhance girls' learning experiences while opportunities to work/practice independently and competitions to demonstrate and compare skill levels should be incorporated to enhance boys' learning experiences.

FMS training, resources and information provided to teachers, coaches and parents may increase the quality of teaching of FMS during PA opportunities (including PE, sport and PA). The provision of space, sports equipment and encouragement to participate in structured and unstructured PA, both during and after school (at home and through extra-curricular activities), are also suggested to ensure both boys and girls receive equal opportunity for the development of both locomotor and object-control proficiency (Hardy, King, Farrell, et al., 2010).

Both age and sex-differences among primary school aged children should be considered to guide and aid the design, development and implementation of early interventions, which based on low FMS levels worldwide, are warranted.

<u>Overweight and Obesity</u>

Research has also examined the relationship between FMS and weight status, which has yielded mixed findings (Bryant et al., 2014; Cliff et al., 2012; Hume et al. 2008; Lubans et al., 2010; Spessato, Gabbard, Robinson et al., 2013). A systematic review of the relationship between FMS and associated health benefits among children and adolescents reported that FMS are negatively associated with weight status, i.e. children with higher FMS levels are a healthier weight than their less skilled counterparts (Lubans et al., 2010). Cliff et al. (2012) who examined the FMS proficiency of 153 overweight/obese children using the TGMD-2 found that the prevalence of mastery in each of the 12 FMS assessed was significantly lower among the overweight/obese sample when compared to the reference US sample ($p < .05$). Similarly, Marmeleira, Veiga, Cansado, & Raimundo (2017) who assessed the FMS proficiency of 6-10 year old children (N=156) using the Bruininks-Oseretsky Test of Motor Proficieny-Short Form, found that normal weight children scored significantly higher than their overweight and obese peers in gross motor skills ($p < .05$). However, in contrast, Spessato, Gabbard, Robinson, et al. (2013) who examined the FMS proficiency level of 4-7 year old Brazilian children (N=178) using the TGMD-2, reported no significant difference in total FMS scores between underweight, normal weight, overweight and obese children ($p > .05$). Hume et al. (2008) who assessed the FMS proficiency of a sample of 9-12 year old Australian children (N=248) using the Department of Education Victoria (1996) assessment tool, reported that normal weight children were significantly better at performing the sprint run than their overweight peers ($p < .01$). However, there was no significant difference between normal weight and overweight/obese children in the kick, throw, strike or vertical jump ($p > .05$). Similarly, Bryant et al. (2014) who assessed the FMS proficiency of 6-11 year old British children (N=281) using the Process Oriented Checklist of the Move It: Groove It manual, found that a significantly larger proportion of normal weight children demonstrated mastery in the sprint run than their overweight/obese counterparts ($p < .05$). Meanwhile, there was no significant difference between normal weight children and overweight children achieving in terms of the proportion of children achieving mastery in the remaining 7 FMS that were assessed (kick, gallop, hop, balance, throw, catch and jump).

Researchers who have found a negative relationship between FMS and weight status and/or a significantly greater FMS proficiency level among normal weight children when compared to their overweight/obese counterparts, have been suggested that the poorer FMS levels of overweight/obese children is due to the excessive body fat of overweight/obese children. It is believed that this excess fat makes it more difficult for overweight/obese individuals to move their body in various movement patterns from one location to another than their leaner counterparts (Southall et al., 2004). Others, however, argue that FMS proficiency levels are independent of fitness (cardiorespiratory and muscular endurance) and physical attributes (height and mass) when assessed using process oriented tools, as the skills are performed over a short time frame (Kim & Lee, 2017).

The participation levels of non-overweight and overweight/obese children in sport and PA may explain the proficiency difference between children of various weight statuses. Overweight/obese children are less likely to participate in non-organised sport and PA than non-overweight children (Kobel et al., 2014) and thus are less likely to engage in the practice of FMS and receive instruction and feedback as a result. Overweight/obese children are also less likely than their non-overweight peers to participate in organised sport (Kobel et al., 2014), where they can receive quality FMS instruction, correction and feedback from coaches and also spend time practicing basic movement skills.

Environmental Factors

Throughout the process of FMS development, it is proposed by Newell's Theory of Constraints that movements are either facilitated or limited by the interaction of the individual, task and the environment in which the movement occurs (Newell, 1986). While several individual constraints have been discussed (including age, sex, weight status), it is also important to consider environmental factors which may influence FMS including socioeconomic status, rurality (locality) and cultural background.

Socioeconomic Status

Socioeconomic status (SES) has been found to be an environmental factor associated with FMS proficiency levels among children (Hardy, Reinten-Reynolds, Espinel, Zask, & Okely, 2012). Children from low socio-economic status or from low-income communities have commonly been reported to demonstrate lower motor skill competence compared to children from high/middle socio-economic backgrounds (Morley, Till, Ogilvie, & Turner, 2018; Booth et al., 1999; Hardy, King, Espinel, Cosgrove, & Bauman, 2010; Hardy et al., 2012). A recent study conducted in the UK among 4- to 7-year olds (n=369), which assessed motor skill proficiency using the Bruininks-Oseretsky Test of Motor Proficiency, 2nd Edition Brief Form, reported significantly greater gross motor total score among children from both high (10.0 ± 5.0) and middle (9.4 ± 4.4) SES than children from low SES (8.3 ± 4.4) ($p = 0.04$). Similar findings have been reported in Australia, in which an association was found between low movement competency and low socio-economic status (Booth et al., 1999; Hardy, King, Espinel, et al., 2010; Hardy et al., 2012). In the study of Booth et al. (1999) which assessed FMS proficiency among 5518 NSW school students (Year 4, 6, 8 and 10; mean age: 9.3-15.3 years) using the Department of Victoria assessment tool, a significant association was found between SES tertile and the proportion of girls achieving mastery/near mastery levels in four of the skills (vertical jump, catch, overhand throw and kick). A significant association was also found among the boys between SES tertile and the proportion of boys achieving mastery/near mastery in the run and forehand strike. More recently, Hardy et al (2012) also revealed that those from low SES often exhibit lower competency than those from high SES. It was reported that Grade 2 boys (approximately age 6) were twice as likely to have low competency in object-control skills than those from high SES. Similarly, primary school girls were twice as likely to have low competency in the vertical jump.

As FMS has been shown to be associated PA levels, it is not surprising that those from low SES have been reported to have significantly lower PA levels than those from middle or high SES (Department of Health and Ageing 2008; Hardy, King, Espinel, et al., 2010). The prevalence of low FMS proficiency among socially disadvantaged children may result in negative spiral of disengagement from PA and participation in sport. Therefore, motor skill interventions aimed at improving FMS are warranted among this population to help increase PA and sport participation and to reap the associated health benefits. One such intervention which has been shown to be effective among children from low-income communities is the 12-month multicomponent FMS and PA intervention known as the Supporting Children's Outcomes using Rewards, Exercise, and Skills (SCORES) intervention (Cohen et al., 2015). Following this intervention, children were found to have significantly greater FMS, daily MVPA and cardiorespiratory fitness. This evidence provides support for the implementation of such interventions in primary schools in low-income communities to increase FMS proficiency among children from low SES.

Rurality

FMS proficiency levels with respect to geographical location in terms of rurality (i.e. rural versus urban) is an environmental factor that has gained some interest, albeit limited. In a review of the correlates of PA among children, Sallis et al. (2000) reported environmental factors among the least-studied correlates of PA and therefore, it is not surprising that there is limited research relating to the relationship between FMS proficiency and rurality/millieu. A study of 5518 Australian school students (New South Wales) from Years 4,6,8, and 10 (mean age: 9.3-15.3) assessed the FMS proficiency of urban and rural children using the FMS: A Manual for Classroom Teachers (Department of Victoria, 1996). Six FMS were assessed including the run, vertical jump, catch, overhand throw, forehand strike and the kick. The proportion of children demonstrating Advanced Skills, which included those who achieved either mastery (correct performance of all components of a FMS) or near mastery (performance across test trial with the presence of all but 1 component), were compared between students attending urban schools and those attending rural schools (Booth et al., 1999). Findings revealed there were no significant differences in the prevalence of Advanced Skills between children (either boys or girls) attending rural and urban schools across any of the six FMS assessed. In each of the individual year groups assessed, there was also no difference in the percentage of children displaying Advanced Skills between those attending urban and rural schools (Booth et al., 1999).

Similarly, in the 2004 NSW Physical Activity and Nutrition Survey (Booth et al., 2006), no significant differences were evident in the prevalence of Advanced Skills among children (Year 2, 4, 6, 8, and 10) by rurality for the run, vertical jump (all years except Year 6 boys), side gallop (all years except Year 6 girls), leap, kick and overarm throw. For the vertical jump in Year 6 (mean age: 13.3 years), the prevalence of Advanced Skills among boys from urban schools (65%) was significantly greater than those attending rural schools (40.9%). Similarly, for the side gallop in Year 6 (mean age: 13.3 years), the proportion of girls displaying Advanced Skills was significantly greater among those attending urban school (75.1%) than girls from rural schools (61.8%). This evidence suggests that children attending both urban and rural schools display similar overall FMS proficiency levels.

Furthermore, an investigation into the prevalence and correlates of low fundamental movement skill competency in children revealed that while SES and cultural background were associated with low competence, there was no rural-urban differences in children's low FMS competency (Hardy et al., 2012). In contrast, the assessment of FMS proficiency of 319 urban and 60 urban children (pre-Kindergarten age) living in Alabama, conducted using the TGMD, reported that children attending urban schools were found to demonstrate significantly greater object-control proficiency than their rural counterparts, while demonstrating similar locomotor proficiency (Rudisill, Martin, Weimar, Wall, & Valentini, 2002). However, the small rural sample (n=60) in comparison to the urban sample (n=319) must be noted in the study of Rudisill et al. (2002). The young age of the children must also be considered, with children yet to begin Kindergarten (< 5 years of age) included. Therefore, although research investigating differences in FMS proficiency among children by rurality is limited, existing evidence suggests that children attending urban schools display similar FMS proficiency to those attending rural schools. However, future research is recommended to investigate this further.

Cultural Background

Cultural background has been found to be a correlate of low FMS competency (Hardy et al., 2012). Hardy et al. (2012) examined the characteristics of Australian school-children and adolescents who completed the NSW Schools Physical Activity and Nutrition Survey in 2010 who display low FMS competency. Results revealed a strong association among boys between low FMS competency and the probability of being from a non-English speaking cultural background (specifically those from Middle Eastern and Asian cultural backgrounds). It was found that primary school boys from non-English speaking backgrounds in Grades 4 and 6 (approximate age: 9 years and 11 years, respectively) were more likely to demonstrate low object-control competency than English-speaking boys. Low competency in the kick and vertical jump was observed among non-English speaking boys. It has been suggested that these differences may be due to the higher prevalence of overweight/obesity among the children of Middle Eastern background as well as the low proportion of the children from Middle Eastern and Asian backgrounds reaching the recommended PA guidelines (Hardy, King, Espinel, et al., 2010). In contrast, no consistent associations were evident between cultural background and low competency among girls (Hardy et al., 2012). A recent study investigating the impact of cultural background on FMS compared the FMS proficiency (assessed using the TGMD-2) of 9- to 11-year-old children (n=261) from culturally and linguistically diverse background. Results revealed greater object-control proficiency levels among English-European children when compared with and Asian-speaking children (Barnett et al., 2018). While the relationship between cultural background and FMS has not been extensively tested, existing research suggests that cultural factors may influence FMS proficiency levels among children. This evidence suggests that quality motor skill interventions among children from non-English speaking backgrounds are warranted to increase FMS proficiency as higher FMS proficiency is associated with numerous health benefits.

Current FMS Proficiency Levels in Ireland

To date, limited published research exists that has examined FMS levels among Irish primary school children. Recently, Farmer et al. (2017) assessed the FMS proficiency levels of 8- to 12-year-old primary school girls (*n*=160; mean age: 10.7) in conjunction with the components of the TGMD, TGMD-2 and the Get Skilled: Get Active resource, revealing low FMS proficiency among this cohort. It was reported that only three girls (2%) possessed mastery across all seven skills assessed. The vertical jump and skip were identified as the poorest skills (with <40% achieving mastery) with the kick found to be the best performed skill (68% achieved mastery). A study including the assessment of FMS in Northern Ireland was conducted by Breslin et al. (2012), although the scoring protocol assessment tool used, which was developed based on the existing BOT and MAB-C assessment tools, was not described nor were the current levels among the cohort reported. However, several recent studies among Irish adolescents have found low FMS proficiency among this cohort. In an evaluation of 242 first-year post-primary school children (12- to 13-year-olds) (O'Brien et al., 2016), it was found that only one child demonstrated mastery in all 9 FMS tested (assessed based on components from the TGMD, TGMD-2 and the Victorian Fundamental Motor Skills Manual). The percentage of children demonstrating mastery failed to exceed 50% in five of the nine FMS tested (strike, overhand throw, skip, horizontal jump and vertical jump), with the exception of the catch (68%), kick (83%) and run (87%). Sex-related differences were found in both mean composite FMS score and object-control score, with boys demonstrating greater proficiency than girls. Using the same assessment tool, Lester et al. (2017) also found low levels of FMS among 1st to 3rd year post-primary school children (*n*=181; mean age: 14.4) with less than 50% of the children from each of the three year groups achieving mastery in six of the 10 skills tested (kick, dribble, strike, vertical jump, throw and horizontal jump). Furthermore, a progressive decline in object-control proficiency was found from 1st to 3rd year. Therefore, while there is a dearth of data relating to the FMS levels among Irish primary school children, the FMS proficiency levels among Irish adolescents suggest primary school children enter second level education with poor FMS proficiency.

International comparisons reveal that Irish children have low PA levels as well as high levels of sedentary behaviour (Tremblay, 2014). In the 2016 Ireland North and South Report Card on Physical Activity for Children and Youth, a grade of 'D' (poor) was reported for overall physical activity levels, indicating less than 40% of Irish children and youth are physically active (Research Work Group for Ireland's Report Card on Physical Activity in Children and Youth, 2016). Furthermore, according to a WHO study involving 53 European countries, Ireland has been predicted to be the fattest of these nations by 2030 (Webber et al., 2014) and thus, an investigation into the FMS levels of Irish children may highlight FMS as an area with the potential for improvement. Based on the associations between FMS and numerous benefits, improving FMS may be one such mechanism to help promote health and wellbeing and combat the rise in obesity that has been predicted in our country.

<u>Current Practice within the Irish Physical Education Curriculum and Coaching in Ireland</u>

At present in Ireland, it is recommended that Irish primary school children engage in 60 minutes of PE per week (Department of Education and Science, 1999). This is the lowest amount of PE time among all EU countries (European Commission/EACEA/Eurydice, 2013), with children in the UK and France engaging in two and three times more PE than this recommendation, respectively, every year (Bardens, Long, & Gillie, 2012; European Commission/EACEA/Eurydice, 2013). In contrast to 89% of countries where primary school PE is a legal requirement (Hardman, 2008), this 60 minute time allocation for PE in Ireland is a mere recommendation; one that only 35% of Irish primary schools follow (Woods et al., 2010). A study by Woods et al. (2010) reported that the average time spent in PE per week in Irish primary schools was 46 minutes. Furthermore, Halbert and MacPhail (2005) reported that the average time spent in PE in Irish primary schools ranged from 12-60 minutes and that three-quarters of Irish primary school students had less than 30 minutes of PE each week.

The current Irish PE curriculum consists of six strands; Games, Athletics, Gymnastics, Dance, Outdoor Adventure and Aquatics (Department of Education and Science, 1999), with little focus on the development of correct FMS technique. Despite the inclusion of six strands in the curriculum, Woods et al. (2010) reported that in reality, Irish primary school PE classes are dominated by team sports (an aspect of the games strand), with relatively large proportions of children reporting no engagement in activities from the other five strands during PE during their previous year in school. (A total of 89% of children reported that they did not participate in outdoor adventure while 70%, 57%, 50% and 42% reported not participating in gymnastics, dance, aquatics, and athletics, respectively).

Currently, in the teacher training colleges of Ireland, limited PE training is provided. For example, in one particular teacher training college, PE included in a module called 'Drama and PE' accounts for only 10 of the 120 programme credits (8%) across the compulsory subjects of Year 1 and 2, with a large amount of the time in Years 3 and 4 spent teaching in schools. Similarly, in another college, Physical Education, which is included in the 'Social, Personal, Health and Physical Education' module, is only provided in two of the eight college semesters. Research worldwide has also found that classroom teachers have often expressed dissatisfaction with their PE teacher training (Decorby, Halas, Dixon, Wintrup, & Janzen, 2005; Morgan & Bourke, 2005), stating that more extensive training and of longer duration is required. The importance of increasing teacher confidence and competency in delivering effective PE is vital as research has shown that low confidence, inadequate training and limited support and resources have been found to be major barriers to successful PE delivery (Curtner-Smith, 1999; Decorby et al., 2005; Graham, 1991; Morgan & Bourke, 2005). Recently, the Professional Development Service for Teachers (PDST) have developed the 'Move Well, Move Often' programme and resource, which aims to provide professional development in physical literacy (through FMS) (Professional Development Service for Teachers, 2018). The resource includes a Teacher Guide and three Activity Books and additional material including videos and sample lessons are also included. Phase 1 of the programme explores locomotor skills and Phase 2, which is currently taking place explores the stability skills, especially through the dance and gymnastics strands. Although these training and professional development opportunities are available, each school may only nominate two teachers to attend the seminars.

The importance of FMS development has recently been acknowledged by Sport Ireland by its inclusion in the Lifelong Involvement in Sport and Physical Activity (LISPA) framework (Sport Ireland, 2018) (Figure 2.4).

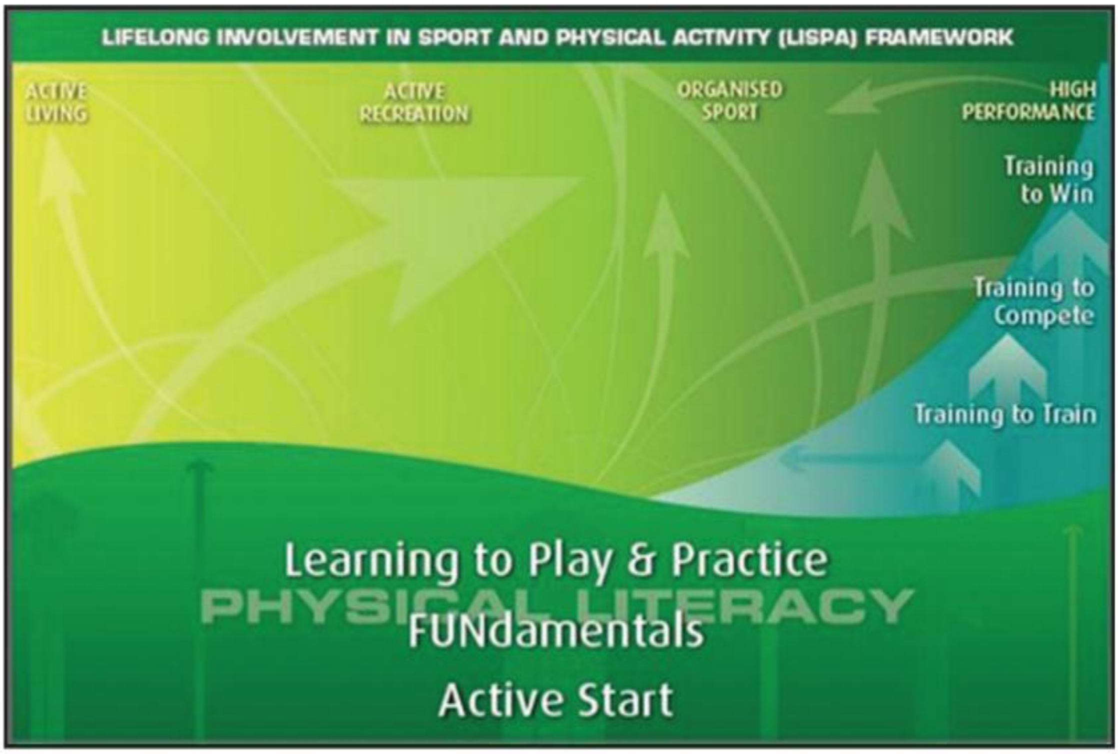

Figure 2.4: Lifelong Involvement in Sport and Physical Activity (LISPA) framework

The first three phases of the LISPA (Learning to Play and Practice, FUNdamentals, and Active Start) focus on physical literacy and include the development of FMS. This framework highlights the importance for children to develop the ability to perform FMS to facilitate lifelong participation in PA and promote competence and performance throughout the later stages of the model: Training to Train, Training to Compete and, Training to Win (Sport Ireland, 2018). For example, if a child cannot run competently, participation in activities/sports such as soccer, basketball, and rugby may be challenging.

2.6 Interventions

Research has shown that the ability to perform FMS correctly (i.e. FMS proficiency/mastery) is associated with numerous health benefits and is important for the holistic development of children (Barnett, Stodden et al., 2016). However, despite children’s potential to master FMS by the age of seven (Branta, Haubenstricker, & Seefeldt, 1984; Gallahue & Ozmun, 2006), evidence from studies worldwide have reported less than desired levels of FMS proficiency among primary school aged children (Bardid et al., 2016; Bellows et al., 2013; Bolger et al., 2017; Bryant et al., 2014; Khodaverdi & Bahram, 2015; Kordi et al., 2012; Mitchell et al., 2013; O’Brien et al., 2016; Spessato, Gabbard, Valentini et al., 2013). As these skills are not acquired naturally (Barnett, Stodden et al., 2016; Logan et al., 2011), this evidence would suggest children do not receive the quality instruction, practice and reinforcement required in order to become proficient (Gallahue et al., 2012; Pang & Fong, 2009). Therefore, effective strategies and interventions during childhood are warranted to enhance the FMS levels of children which will facilitate PA and sport participation throughout the lifespan and the acquisition of numerous associated health benefits.

The primary school setting offers an ideal opportunity for the development of FMS. During the primary school years, children spend approximately 40% of their waking day in the school setting, throughout the academic year (Department of Education and Skills, 2017a). In addition, primary schools often possess the necessary resources including teachers, facilities, equipment, scope within the Physical Education (PE) curriculum and access to all attending children (including those who are at risk of developmental delays, being inactive and/or overweight/obese) to facilitate FMS development (Lander, Eather, Morgan, Salmon, & Barnett, 2017; Wiart and Darrah, 2001). As a result, many school-based interventions, which have adopted various strategies and approaches, have been implemented and their effectiveness at improving movement skill proficiency evaluated.

School-based PA Interventions

In a systematic review of the effectiveness of PA interventions (school-based) on PA and physical fitness in children and adolescents (Kriemler et al., 2011), six studies that also evaluated motor skill competence were included. It must be noted that in these studies, a variety of definitions and measures of motor skills were used (Boyle-Holmes et al., 2010; Graf et al., 2008; Salmon, Ball, Hume, Booth, & Crawford, 2008; Sollerhed & Ejlertsson, 2008; Verstraete, Cardon, De Clercq, & De Bourdeaudhuij, 2007; Walther et al., 2009). Of these six studies, four reported a significant positive improvement in motor skills following a PA-based intervention (Boyle-Holmes et al., 2010; Graf et al., 2008; Salmon et al., 2008; Sollerhed & Ejlertsson, 2008). Boyles-Holmes et al. (2010) found that the two-year implementation of the EPEC curriculum (Michigan's Exemplary Physical Education Curriculum) among 4th and 5th grade children in eight elementary schools significantly improved proficiency in the three skills assessed, which included the forehand strike, lift and carry and leap (improvements among 5th graders only) using an observation checklist specifically developed. Similarly, improvements in motor skill ability, identified using the EUROFIT test battery, was also found in Sweden following an increase in the number of weekly PE lessons from two to four between 2000-2003 (Sollerhed & Ejlertsson, 2008). In the study by Graf et al. (2008), a PA intervention delivered as part of the Children's Health Intervention Trial (CHILT) project was delivered across four academic years from 2001-2005 in 12 schools in Germany. The intervention included 20-30 minute weekly health education classes, daily physical activity lessons, encouragement of PA during leisure time, modifications to PE lesson plans and teacher training. An evaluation of motor skill proficiency and motor coordination was conducted using the KTK, with a significant improvement found in only two of the four motor tasks.

In a study undertaken by Salmon et al. (2008), involving the implementation of the Switch-Play intervention, proficiency was assessed in six FMS using the Department of Victoria resource (Department of Education, Victoria, 1996) with improvements reported only among girls.

In contrast, Verstraete et al. (2007) reported no significant intervention effect on motor skills using the EUROFIT test battery following a comprehensive two-year PA intervention (including a health-related PE programme, an extracurricular PA promotion programme and classroom-based PA education lessons) delivered in eight elementary schools. Similarly, Walther et al. (2009) observed no significant motor ability improvements among 6th grade children, following a one-year PA-based intervention involving daily school exercises classes, assessed using the KTK. Therefore, inconsistent findings exist in relation to the effectiveness of PA-based interventions in improving motor skill proficiency.

As these interventions were primarily aimed at improving PA, these findings may be due to the limited quality FMS instruction and feedback provided during the intervention, despite increases in practice opportunities for FMS, all of which are essential elements for FMS development (Gallahue & Ozmun, 2006). While various strategies to improve PA levels were implemented in each intervention, only the studies conducted by Salmon et al. (2008), Boyle-Holmes et al. (2010) and Sollerhed and Ejlertsson (2008) included an FMS component within the PA-based intervention. These findings suggest that while an increase in PA provision may increase practice opportunities for FMS, interventions with an FMS-specific focus, including quality instruction and feedback as well as practice opportunities may be warranted to facilitate greater FMS development.

School-based Motor Skill Interventions

School-based motor skill interventions, of various designs, duration and approaches, have been reported in systematic reviews by both Logan et al. (2011) and Morgan et al. (2013). The meta-analysis conducted by Logan et al. (2011), assessing the effectiveness of motor skill interventions which evaluated FMS using the TGMD or TGMD-2, including 11 studies and provides evidence for the effectiveness of motor skill interventions to improve locomotor (*Cohen's d* = .41; small effect), object-control (*Cohen's d* = .45; small effect) and overall FMS competence (*Cohen's d* = .39; small effect). A limitation of this review and meta-analysis is that most studies included children who were developmentally delayed or at risk of delay in FMS proficiency and so the potential to increase FMS from baseline levels may be greater than that expected among typically developing children. However, Morgan et al. (2013) provide further support and evidence for the implementation of FMS interventions among youth. A review of 19 motor skill interventions across nine countries, with sample size ranging from 30-1045 children, including school-, home- and/or community-based interventions for children and adolescents (age range: 5-18 years) aimed to improve FMS was conducted. Large effect sizes for overall (*standardised mean difference* = 1.42; large effect size) and locomotor (*standardised mean difference* = 1.42; large effect size) proficiency have been reported, with a medium effect size (*standardised mean difference* = .63; medium effect size) reported for object-control proficiency.

A 12-month school-based multicomponent PA and FMS intervention, conducted among primary school children from low socioeconomic status in Australia, known as the 'SCORES' intervention, was found to improve overall FMS proficiency and cardiorespiratory fitness, while daily moderate-to-vigorous PA (MVPA) levels observed prior to the intervention were also sustained (Cohen, Morgan, Plotnikoff, Barnett, & Lubans, 2015). The SCORES intervention involved numerous elements including teacher professional development, student leadership workshops, PA promotion, parent involvement and strategies to improve links between the school and local community (Cohen, Morgan, Plotnikoff, Barnett et al., 2015; Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2015). Similarly, the six-month 'Move It Groove It' multicomponent intervention among 7- to 10-year-old Australian children (*n*=1045) incorporated a whole-school approach, involving project teams, teacher professional development and a 'buddy program', as well as a project website and funding for equipment purchase (van Beurden et al., 2003). Similar positive results were observed following this intervention with improvements made in all 8 FMS assessed using the Get Skilled: Get Active resource, with a 16.8% improvement in overall proficiency. Similarly, significant FMS improvements were observed in all 12 skills tested, following the Project Energize intervention among 5- to 12-year-olds in New Zealand, involving PE specialists (called Energizers) who provided mentorship to classroom teachers, with individual skill improvements ranging from 13.7% to 76.3% (Mitchell et al., 2013). Furthermore, a five-month school-based 'Go2Play' Active Play intervention, assessed using the TGMD-2 and delivered in seven primary schools in Scotland, consisting of a one-hour outdoor session provided by local play workers, was also found to be effective at improving FMS levels (Johnstone, Hughes, Janssen, & Reilly, 2017). During the first 30 minutes of each Active Play sessions, children engaged in fun, inclusive activities incorporating one specific FMS, while the second 30 minutes was allocated to free play providing children with the opportunities to practice the learned FMS. Results revealed intervention effects for locomotor, object-control and overall FMS proficiency among the intervention group (with significant improvements in GMQ, subset standard score, and percentile) (Johnstone et al., 2017).

In summary, the systematic review by Morgan et al. (2013) provides evidence for the effectiveness of school-based motor skill interventions at improving locomotor (large effect size), object-control (medium effect size) and overall proficiency (large effect size) among children. The review by Logan et al. (2011), although included studies involving children with/at-risk of developmental delay, also provides indication that children's FMS proficiency levels increases following motor skill intervention (small effect sizes reported for both subtests and overall FMS). Furthermore, the findings of more recent studies including the 16.8% mean improvement in overall FMS proficiency reported by van Beurden et al. (2003), the increase in the proportion of children achieving mastery by a minimum of 13.7% in 12 skills observered by Mitchell et al. (2013) and a 21-26% increase in subtest scores reported by Johnstone et al. (2017) following motor skill interventions indicate FMS improvement among children may be achieved through the implementation of motor skill interventions.

Effective Intervention Approaches

To aid the development and implementation of effective motor skill interventions, Tompsett et al. (2017) conducted a review of pedagogical approaches used in FMS interventions, with the aim to identify intervention components and strategies most consistently associated with improvement in FMS. In the 29 studies selected, 27 were effective at improving FMS proficiency, incorporating strategies such as:

- adopting a multi-disciplinary approach
- of long duration (> 6 months),
- providing multiple sessions per week,
- delivered by a PE specialist
- incorporating parental involvement (e.g. 'at home' practice assisted or supervised by parents, parent evenings) (Tompsett et al., 2017)

Other reviews which have evaluated the effectiveness of motor skill interventions on improving FMS have also reported similar FMS intervention components or pedagogical approaches that were commonly found within numerous effective interventions (Morgan et al., 2013; Riethmuller, Jones, & Okely, 2009). Similar to those proposed by Tompsett et al. (2017), a review of 19 interventions conducted by Morgan et al. (2013) reported that effective intervention characteristics included the delivery multiple lessons per week, the use of a PE specialist/substantial teacher training (to ensure children receive quality instruction and feedback and engage in developmentally appropriate activities) and strategies involving parents (including home based FMS tasks) in the intervention. Another common element found in effective interventions by Morgan et al. (2013) was the incorporation of a mastery climate approach (focussing on success, challenge and autonomy) during PE-based interventions with a specific FMS-focus. Interventions delivered in an after-school setting, due to the crowded school curriculum, were also found to be successful. In addition, Riethmuller et al. (2009), based on findings from 17 studies which included interventions to improve motor development among young children, recommended that intervention implementation should involve both teacher and researcher (PE specialist), that parent involvement is essential to promote FMS development in the home setting and also that intervention methods should be appropriate and should follow the CONSORT or TREND Statements. In terms of evaluating effective intervention approaches, it has been acknowledged that due to the limited detail provided in numerous studies regarding intervention design, dose, duration and intensity, it can be difficult to establish which intervention components were most important and effective (Morgan et al., 2013). It is suggested that future intervention studies should provide an in-depth description of intervention design, dose, duration and intensity to ascertain the most effective components to aid FMS development (Logan et al., 2011; Morgan et al., 2013).

The strong, positive evidence revealed for the effectiveness of motor skill interventions, would suggest that such interventions within primary schools are warranted immediately to improve FMS levels. Based on the existent association between FMS and numerous health benefits (Barnett, Stodden et al., 2016; Cattuzzo et al., 2016; Lubans et al., 2010; Robinson, Stodden et al., 2015) as well as the current global health crisis, motor skill interventions aimed at improving FMS, may prove invaluable as a strategy (or form part of a comprehensive strategy) to help combat physical inactivity and childhood obesity. Therefore, it is recommended that effective motor skill interventions be delivered on a larger scale in primary schools.

School-based PA/FMS Interventions in Ireland

Despite positive findings from the systematic reviews of Logan et al. (2011) and Morgan et al. (2013) and many other motor skill interventions at improving FMS (Bardid et al., 2017; Cohen, Morgan, Plotnikoff, Barnett et al., 2015; Johnstone et al., 2017; Mitchell et al., 2013; van Beurden et al., 2003), as of yet, there is no published data relating to the implementation or evaluation of such interventions in Ireland among primary school aged children.

However, the Youth-Physical Activity Towards Health project (Y-PATH), a 9-month multicomponent school based intervention (Belton, O'Brien, Meegan, Woods, & Issartel, 2014), has successfully been implemented among 12- to 14-year-old students (1st year secondary school students) and shown to be effective at improving PA and FMS among this cohort (McGrane, Belton, Fairclough, Powell, & Issartel, 2018; O'Brien, Issartel, & Belton, 2013). The Y-PATH intervention consisted of a printed resource containing two parts that were developed for the PE teachers in the intervention school. The first component consists of six lesson plans, each containing a Health-Related Activity (HRA), PA and psychosocial focus; while the second component consisted of a guide of how to incorporate HRA, psychosocial and FMS elements into the strands of the Irish Physical Education Curriculum for Junior Cycle. PE teachers, delivering the intervention, also participated in a one-day training workshop and received four display posters. A student handbook, mirroring the resources provided to the teachers, as well as including a PA log book which allowed students to monitor their PA levels, was provided. All non-specialist PE teachers participated in two one-hour workshops, encouraging and informing teachers how to be active role models and encourage PA participation. A member of the Y-PATH research team also organised information leaflets and an information session with all parents of the participating students to increase awareness of the importance PA and approaches that can be used to encourage PA among adolescents (McGrane et al., 2018). The FMS tested included 15 skills: run, skip, gallop, slide, leap, hop, horizontal jump and vertical jump (locomotor) and kick, catch, throw, strike, roll and dribble (object-control) as well as balance (stability). Each skill was evaluated using the TGMD (Ulrich, 1985), TGMD-2 (Ulrich, 2000) and Victorian Fundamental Motor Skills manual (Department of Education, Victoria, 1996). Evaluation of the intervention revealed that the intervention group had significantly greater improvements in both overall FMS proficiency and PA levels than the control group. Significant improvement was evident in the intervention group for object-control proficiency only (*Cohen's d* = .35; small effect). However, further analysis revealed that improvements in FMS proficiency were evident between baseline and retention (conducted four months after post-testing) for both locomotor (*Cohen's d* = .75; medium effect) and object-control (*Cohen's d* = 1.31; large effect) providing evidence that the Y-PATH is an effective multicomponent PA and FMS among an adolescent Irish population (McGrane et al., 2018).

Therefore, given the low levels of FMS among primary school aged children globally and more specifically in Ireland (Bolger et al., 2017), the design, development, implementation and evaluation of interventions aimed at improving children's FMS are warranted among Irish primary school children. Should such an intervention prove effective and feasible, its implementation on a larger scale across all schools nationwide (or its integration into the Physical Education curriculum) may positively impact the FMS, PA and obesity levels of Irish children.

2.7 Conclusion

In conclusion, FMS are basic movements and foundation for the acquisition of more complex sport-specific skills. FMS which facilitate physical activity and sports participation are associated with numerous health benefits, with those with higher FMS proficiency found to have higher levels of PA, self-esteem and a more favourable weight status. FMS development has an important role to play, not only in the overall motor development of children but the holistic development of children. Recent evidence has revealed less than desired FMS levels among children, across many countries worldwide. Therefore, PA and FMS interventions which have been found to be an effective strategy to improve FMS are warranted. More specifically, in Ireland, low FMS (Bolger et al., 2017) and PA levels and the existing high levels of sedentary behaviour and overweight/obesity based on international comparisons (Tremblay, 2014; Webber et al., 2014), highlight the need for effective FMS-based interventions in Irish primary schools in an attempt to positively impact the health of the population.

While the current chapter has provided an overview of existing literature relating to FMS, motor skill assessment tools, the health benefits associated with FMS, motor development, FMS proficiency levels worldwide and interventions that have aimed to evaluated FMS as an outcome, the following chapter outlines the methods used in the current research. More specifically, details relating to the school recruitment process, intervention design, data collection, process evaluation and data analysis are provided.

Chapter 3:

Methods

3.1 Introduction

This chapter serves to describe the methodological approaches adopted during the research, including school and participant recruitment, intervention content and delivery, as well as the measurement procedures used.

This research includes the following:

- a systematic review of the fundamental movement skill (FMS) proficiency levels among primary school aged children (4-13 years) worldwide (Chapter 4)
- a cross-sectional analysis of the current FMS levels among a cohort of Irish primary school children (Chapter 5)
- an investigation into the relationship between children's perceived and actual FMS competence and physical activity (PA) levels (Chapter 6)
- a quasi-experimental study examining the effectiveness of two school-based interventions, namely a PA intervention, delivered across academic year 2014/2015 (AY14/15) and a multicomponent FMS-based intervention, delivered across academic year 2015/2016 (AY15/16), on improving the fundamental movement skill proficiency among Irish primary school children (Chapter 7)

Data collection was conducted in three primary schools in Cork, Ireland between October 2014 and May 2016, at four different time-points; prior to and at the end of each intervention. Specific methodological approaches adopted in each of the above investigations are described in their respective chapters (i.e. Chapters 4-7).

3.2 Ethics

Ethical approval was sought from the Cork Institute of Technology Research Ethics Review Board to conduct the research and was granted in September 2013. Throughout the research process, all necessary measures were taken to ensure the safety of all participants. Consent forms for participation in the research were required to be completed by both children and parent. Each participant was also assigned a unique ID number to maintain anonymity. All appropriate data security procedures were adhered to, ensuring confidentiality of all participant information. All files were safely and securely stored in a locked cabinet in a locked office on the college campus, accessible to only the researchers involved in the study.

3.3 School Recruitment

All existing primary schools (*N*=349) in Cork City and County for the academic year 2012/2013 were identified using the Irish Department of Education and Skills website (Department of Education and Skills, 2013). Questionnaires subsequently were distributed to each School Principal to ascertain the interest in implementing a *Project Spraoi*, physical activity and healthy eating intervention. All schools who returned the questionnaires (*n*=151: 43%) expressed an interest to implement the intervention. Further inclusion criteria for participation specified that the schools were (i) in close proximity (within approximately 20 km) to Cork Institute of Technology, (ii) consisted of between 100-300 students, (iii) willing to implement the *Project Spraoi* intervention and (iv) not participating in any other physical activity (PA) and/or healthy eating intervention in the school (Coppinger et al., 2016).

The current study involved the recruitment of three schools meeting these requirements, which comprised of two intervention schools (two urban single sex: one boys and one girls) and one control school (rural mixed), for AY14/15 and AY15/16. In September 2014, a meeting of the postgraduate researcher and respective School Principals and/or lead teachers was organised, in which a detailed description of the study was provided, with the opportunity for discussion about the research. A Memorandum of Understanding (Appendix E.1), designed by the *Project Spraoi* Research Team and confirming the school's willingness to fully participate to the best of their ability, was signed by each School Principal. Prior to commencing the intervention, the lead researcher conducted an introduction meeting and a needs analysis with all staff from the intervention schools to identify areas of PE and physical activity requiring improvement in the school (Appendix E.2). This meeting involved a brainstorming session in which staff, in small groups of 3-4, were required to consider (i) what area of physical activity/PE they felt was done well, (ii) what area of physical activity/PE they felt required work and (iii) how they thought the 'Energizer' could assist them. This process was then repeated focusing on the area of healthy eating/nutrition within the school. This information was then discussed by the group as a whole and relayed on to a flipchart by the lead researcher. Following the meeting, the data collated was analysed and used in the development of an action plan for each respective school. Students in the control school did not receive the intervention during the 2014-2016 period. However, similar to both intervention schools, outcome measures were evaluated for students in the control school at the beginning and end of each academic year.

3.4 Participant Recruitment

See Chapters 5-7 for information participant recruitment for each respective studies.

3.5 The 'Energizer'

The role of the qualified specialist, i.e. Energizer, is described in Chapter 7.

3.6 Intervention Design

Two interventions, adopting a whole-school approach, were delivered to all classes in the two intervention schools, each delivered across one academic year. In Year 1 (AY14/15), a PA intervention was designed and delivered, adapted from 'Project Energize', a health promotion intervention in New Zealand, which has been successfully implemented for over 10 years among primary school aged children (Rush et al., 2016). The 'Project Energize' intervention was tailored for implementation in an Irish setting, accounting for cultural, environmental and curriculum differences (including most popular sports, weather, facilities, open space and time available for PE and PA within the school curriculum) between the countries (Coppinger et al., 2016).

In Year 2 (AY15/16), a multicomponent FMS-based intervention, while also incorporating PA-based activities and initiatives, was designed and delivered to all classes in both intervention schools, adopting intervention approaches recommended by Riethmuller et al. (2009) and more recently by Tompsett, Sanders, Taylor, and Cobley (2017). This intervention was also based on other FMS interventions including Project Energize in New Zealand (Mitchell et al., 2013), the SCORES intervention in Australia (Lubans et al., 2012) (both delivered among primary school aged children) and the Y-PATH, which was shown to be successful among Irish adolescent school children (O'Brien et al., 2013). Table 3.1 displays a description of the intervention components which were incorporated into both interventions as well as those which were specific to each intervention.

Table 3.1: Intervention components incoporated in each intervention

Intervention Component	**Description (including frequency and duration where applicable)**	
	PA-Intervention	**FMS-Intervention**
Energizer-led session	2 x 25 minute sessions/week	2 x 25 minute sessions/week
Encouragement of 20 minutes MVPA daily	On days on which the Energizer was not present in the school	On days on which the Energizer was not present in the school
Professional Development Workshop	1. Gymnastics (1 x 2 hours) 2. PA-based Workshop (including focus on *huff and puff* activities) (1 x 2 hours)	FMS Practical Workshop (1 x 2 hours)
PA Manual	Distributed to all teachers	
Laminated Project Spraoi PA chart	To be updated daily following PA	
Nutrition Workshops	2 x 25 minute lessons: Lesson 1: Sugar Drinks Lesson 2: Four Food Groups	
Information Sheets	Distributed to parents (each term)	
Tip Sheets	Distributed to all children	
FMS Lesson Plans		Lessons designed were delivered through Energizer-led sessions
FMS Teacher Manuals		Distributed to all teachers
FMS Posters		Set of 3-4 posters for each of the 12 skills (each set were hung in the classroom for a period of 2 weeks)
FMS Homework Manuals		FMS Homework to be completed each school night
FMS 'Get Up, Get Moving' PA Break charts		To be updated daily following PA break or additional PA and scores calculated at the end of each week

School Initiatives	Student Pedometer Challenge Staff Pedometer Challenge	Stride for 5 (2 competitions: 6-8 weeks in duration) 1 Kilometre Challenge (across 5 weeks) Paper Rush (across 6 weeks) PE Student of the Week (chosen at the end of each week) Active Agent (role assigned to the previous PE Student of the Week)

Research reports that interventions based on theoretical models of behaviour change are more successful and lead to greater longer lasting effects (Michie and Abraham, 2004) than those that are not. Further support for the use of a theoretical model base when designing interventions is provided in the review by Lai et al. (2014). It is reported that the FMS interventions included in the review, both of which were based on a theoretical model or framework, had sustained impact on FMS proficiency (Barnett et al., 2009; Salmon et al., 2008). The the Social Ecological Model (SEM) of Health Behaviour is one such theory-based framework that outlines the interaction of individual and environmental factors which influence behaviour (McLeroy, Bibeau, Steckler, & Glanz, 1988). These factors include: (i) individual (e.g. knowledge, skills, attitudes) (ii) interpersonal (family, friends, peers) (iii) organisational (school, social institutions), (iv) community (relationship between organisations) and (v) public policy (state and local laws, rules and regulations). It has been suggested that interventions that employ strategies that simultaneously affect these multiple levels may result in greater and longer lasting health behaviour changes (Stokols, 1992; US Department of Health and Human Services, 1996).

Support for the use of the SEM in primary school based health promotion interventions comes from the positive effects of the Supporting Children's Outcomes using Rewards, Exercise, and Skills (SCORES) intervention (Cohen et al., 2015). The SCORES is a 12-month primary school-based intervention aimed at improving PA and FMS levels among children from low-income communities. The intervention was multi-component and simultaneously targeted multiple levels of factors identified in the SEM through student leadership workshops, FMS homework, the provision of opportunities for children to engage in PA promotion tasks (e.g. writing an article in the school newsletter), teacher development, parent evenings, provision of PA-related equipment to the school, the establishment of a PA committee, the creation of links between the school and community-based PA providers and the implementation of PA policies. The effectiveness of this intervention which positively impacted children's PA, FMS and CRF provides support for the use of the SEM in primary school-based PA and FMS based interventions.

Both interventions in the current study were designed and developed, incorporating the SEM (McLeroy et al., 1988). All of the factors within in the SEM were integrated in the intervention design through the following approaches and strategies (McLeroy et al., 1988):

(i) Individual (intrapersonal) approaches:

- Fun, *huff and puff* (MVPA) sessions were delivered
- On-going support and encouragement was provided to classroom teachers to facilitate a minimum of 20 minutes MVPA for children throughout each school day

These aimed to increase PA levels, FMS levels, cariorespiratory fitness levels and PA enjoyment as well as increasing the awareness of the importance of daily PA and healthy eating.

(ii) Interpersonal approaches:

- Information Sheets about *Project Spraoi* (and the various aspects of the research project and intervention) were distributed to the children to bring home to parents/guardians (Appendix E.3)
- Parents, family and friends were encouraged to participate in PA and FMS activities outside of school, through FMS homework (Appendix D.3) as well as practice for in-school competitions (e.g. Stride for 5, 1 Kilometre Challenge, Paper Rush)
- Healthy eating fridge magnets ('Tip Sheets') (Appendix C.3) were distributed to families, to increase nutritional knowledge among both parents and children and provide parents with meal ideas to promote healthy eating habits
- Parents were encouraged to follow the *Project Spraoi* social media pages (including Twitter (https://twitter.com/ProjectSpraoi?lang=en) and Facebook

(https://www.facebook.com/projectspraoi)) which were updated daily with PA, FMS and healthy eating tips and ideas(http://projectspraoi.cit.ie/)

- The *Project Spraoi* website (http://projectspraoi.cit.ie/) (CIT Project Spraoi, 2018) also provided information about *Project Spraoi*, PA, FMS and healthy eating (including sample PA/FMS activities and healthy recipes)

These strategies aimed to increase knowledge and awareness among parents/guardians about the importance of PA, FMS and healthy eating and also served to help parents/guardians develop healthy habits for their children.

(iii) Organisational approaches:

- Teachers were encouraged to facilitate 20 minutes of *huff and puff* activities for children throughout the school day
- Principal and staff involvement was encouraged through school initiatives and competitions (including prizes for teachers, staff pedometer challenge) as well as progress updates via email
- PA and FMS sessions were modelled twice weekly by the Energizer, i.e. the Energizer demonstrated how to deliver PA/FMS-based lessons and provided teachers with a sample of appropriate games and activities which they could replicate.
- Several professional development workshops were organised (gymnastics, FMS, *huff and puff*)

These approaches/strategies aimed to develop a daily school culture in which 20 minutes of MVPA would be customary for each class and endeavoured to increase PA enjoyment among teachers and staff, as well as students. Workshops and modelled classes were designed to increase teacher knowledge, competence and confidence in delivering PA, FMS and gymnastics lessons.

(iv) Community approaches:

- Links were established with local universities and institutes, who assisted with the provision of resources (including equipment, facilities)

- Local sports stars (including GAA players, athletes and international hockey players) participated in fun activity days
- Guest visits to the schools by local sports stars were also organised at various times throughout the year

These approaches aided the development of strong relationships and associations between school and community.

(v) Public Policy approaches:

- Baseline findings and intervention effects were presented to local authorities as well as at physical activity and health related conferences nationally and internationally

It was hoped that following the presentation of findings, that local and national authorities would acknowledge the necessity for an FMS-based intervention among Irish primary school children with the possibility of providing much needed funding for its delivery across a wider number of schools nationally. Further aspirations included the modification of initial teacher training courses, sports coaching courses and an increase in teacher continuous professional workshops, guided by the findings revealed by the research.

3.7 Interventions

Intervention components are described in Chapter 7.

3.8 Measures

Data were collected by a team of trained evaluators, which was led by the postgraduate researcher, at four time points: October 2014 (pre-PA intervention), May/June 2015 (post-PA intervention), September/October 2015 (pre-FMS intervention) and May/June 2016 (post-FMS intervention). Measurements recorded at all four time points were height, mass, FMS proficiency and physical activity levels. In addition, perceived FMS competence was measured at both pre- and post-FMS intervention (AY15/16).

3.8.1 Anthropometric Measures (see Chapter 5)

3.8.2 Test of Gross Motor Development-2 (see Chapters 5-7)

3.8.3 Physical Activity (see Chapter 6)

3.8.4 Perceived FMS Competence (see Chapter 6)

3.9 Data Collection

A detailed outline of data collection conducted across both interventions (AY14/15 and AY15/16) is presented in Table 3.2. In Year 1, the collection of anthropometric and FMS was conducted across six school days (across both intervention and control schools) in October 2014, prior to the *Project Spraoi* intervention and in June 2015, post-intervention. In Year 2, due to the increased sample and testing components (accelerometry and PC), data collection was conducted across 15 school days (across all three schools) in September/October 2015, prior to the tailored FMS *Project Spraoi* intervention and in June 2016, following the culmination of the intervention.

Table 3.2: Timeline and outline of data collection

	Year 1	**Year 2**
September	Meeting with principal and lead teacher	Meeting with principal and lead teacher
	Needs analysis with staff	Needs analysis with staff
	Participant Recruitment	Participant Recruitment
September/October	Pre-intervention testing	Pre-intervention testing
October-June	PA Intervention	FMS Intervention
June	Post-intervention testing	Post-intervention testing
	Process Evaluation	Process Evaluation
Other	Workshops (delivered at times best suited to each school)	

3.10 Process Evaluation

Several methods were used to conduct a process evaluation of each of the interventions carried out as part of the current research. These included a staff meeting between school staff and the Energizer at the end of the Year 1 intervention, of which findings were used to aid the development of the Year 2 intervention. This meeting consisted of two parts. During the first part, teachers worked in groups of 3-4 to identify positive aspects of the interventions, barriers to delivering 20 minutes PA every day with their classes and ways in which the Energizer could assist them to facilitate children's engagement in 20 minutes PA daily during class time. The second part of the meeting consisted of a whole group discussion where the small groups shared their answers from the group task. Facilitators, barriers and potential improvements to the intervention were subsequently discussed.

During the FMS intervention (Year 2 intervention), time facilitated for FMS practice and PA was monitored through weekly FMS and PA break charts, on which all activity was recorded by the class teacher/students. Process evaluations of each of the interventions delivered as part of the current research was also conducted. Evaluation methods included teacher questionnaires (at mid-point and end-point of the FMS intervention) (Appendix F.1), a write and draw task (Appendix F.2) completed by all participants in the evaluation and several semi-structured interviews with randomly selected children (with prior parental consent).

Teacher questionnaires are a common method used in the process evaluation of school based interventions (Christiansen et al., 2018; Griffin, Clarke, Lancashire, Pallan, & Adab, 2017; Sahota, Rudolf, Dixey, & Barth, 2001; Verloigne et al., 2015). The mid-programme questionnaire used in this research consisted of 12 statements to which teachers were asked to respond to using a 5-point Likert scale (1=strongly agree, 2=agree, 3=undecided, 4=disagree, 5=strong disagree). The statements related to a number of aspects of the intervention; the feasibility of the intervention, teacher engagement, class behaviour following PA sessions, teachers' perception of whether there was an improvement in their students' fitness and eating habits, adaptations to the teachers' own behaviours and knowledge as a result of the intervention. Additionally, the questionnaire consisted of two open ended questions; one that asked teachers to identify positive aspects of the intervention and the other to identify aspects of the intervention that had potential for improvement.

The end of programme questionnaire consisted of 5 Likert scale questions, 4 open-ended questions and also asked teachers to evaluate the quality of the nutrition content, PA content and Energizer competence on a 5-point scale (1=very good, 2=good, 3=OK, 4=poor, 5=very poor). The Likert scale questions related to the enjoyment, feasibility and future of the intervention while the open ended questions aimed to identify (i) aspects of the intervention with potential for improvement (ii) the part of the intervention that teachers enjoyed most (iii) barriers to the intervention and (iv) facilitators of the intervention. These questionnaires were printed and distributed to teacher at the respective time points (i.e. at mid-programme and end of programme). Teachers then returned the questionnaires on completion.

Write and draw activity sheets (Appendix F.2) were distributed to all children in the senior infant, 1st, 4th and 5th classes in the intervention schools. Children were asked to draw a picture and write about what the intervention meant to them. Write and draw has previously been used in child-focused health and PA research (Horstman, Aldiss, Richardson, & Gibson, 2008; Knowles, Parnell, Stratton, & Ridgers, 2013; Kostmann & Nilsson, 2012; McWhirter, 2014). This activity was selected as children often express their thoughts and feelings better using images than words (Enright & O'Sullivan, 2012; Gabhainn & Kelleher, 2002; Koppitz, 1983). It is an inclusive, child friendly, non-threatening activity and allows for the expression of children's views (Bradding & Horstman, 1999). Two children from each of the classes who had completed the write and draw activity were randomly selected to participate in a short interview (approximately 5 minutes) that was held outside the classroom door. Interview questions related to children's completed write and draw activity, the intervention's Energizer-led sessions, the intervention outside of the Energizer-led sessions, FMS and the school environment.

Data collected from these evaluations were analysed by the postgraduate researcher of the current research. Key findings observed from all evaluations relating to the interventions implemented in this research, are discussed in Chapter 8.

3.11 Data Analysis

All data were analysed using IBM SPSS, Version 22. Data were initially tested for statistical assumptions and normality. Categorical and ordinal data are summarised using frequencies and percentages for groups and sub-groups. Numerical data are summarised using means and standard deviations. Data are presented graphically using figures where appropriate. The alpha level required for significance for all statistical tests was $p < .05$. Further statistical analysis undertaken are described in Chapters 4-7.

While the current chapter outlined the methods used in the current research, namely the school recruitment process, the intervention design, data collection and data analysis, the following chapter provides a systematic review of the current FMS levels worldwide.

Chapter 4:

Worldwide levels of fundamental movement skill proficiency among children, measured using the Test of Gross Motor Development-2: A systematic review

4.1 Abstract

Background: FMS proficiency facilitates physical activity (PA) and sports participation and is important for the physical, psychological, social and overall development of children. The aim of this study was to systematically review the levels of FMS proficiency, assessed using the TGMD-2, among children worldwide. **Methods:** This manuscript was drafted following the recommendations of the PRISMA checklist. Prospective studies were identified from searches in Medline [OVID], Sports Discus, ScienceDirect, ERIC, Scopus, PubMed and PsychInfo. For inclusion, studies were required to: (i) include typically developing children of primary school age (4-13 years), (ii) be published in English, (iii) have been published between 2003 and 2018 and (iv) report ≥1 of the following TGMD-2 outcome scores: raw scores (skill, subset or total), standard scores (subset or overall), percentiles (subset or overall) or age equivalent (subset). Extracted data were evaluated based on importance of determinants, strength of evidence, and methodological quality. **Results:** Data from thirty-three articles (27 cross-sectional studies, four intervention studies and two pre-post single group studies), across 16 countries and six continents, were extracted and collated. Weighted mean (and standard deviation) scores were calculated for each FMS outcome score, providing an indication of global FMS levels. Analysis revealed FMS proficiency increases across age during the primary school years, with greater locomotor than object-control proficiency exhibited at each given age, from four to 13 years. Based on standardised scores accounting for age and sex, children worldwide demonstrate *average* FMS levels compared with normative data reported by the TGMD-2. **Conclusion:** This review highlights the existing scope for FMS development among primary school aged children worldwide. These findings reinforce the necessity for the provision of FMS interventions in early education and primary school settings to enhance the FMS levels of children, as

higher levels of FMS proficiency is associated with greater PA participation and a multitude of health benefits.

KEYWORDS: FMS, physical activity, motor learning, pediatrics, motor development, motor skills

4.2 Introduction

Fundamental movement skills (FMS) are basic observable patterns of movement such as running, jumping and catching[1] that facilitate participation in physical activity and sport.[2] They are commonly referred to as the 'building blocks' or foundation upon which more complex, sport-specific skills are based.[1] For example, the overarm throw forms the basis of the technique for the tennis serve, badminton overhead clear and javelin throw among others.[3,4] FMS are generally divided into three sub categories: (i) locomotor skills involving the movement of the body from one location to another (e.g. running and jumping), (ii) object-control skills involving the manipulation of an object (e.g. throwing and kicking) and (iii) stability skills involving the acquisition and ability to maintain balance, both static and dynamic (e.g. balancing and twisting).[5] These skills are not acquired naturally[6–8]; rather, they must be learned and practiced[8] through quality instruction, practice opportunities and feedback[8–10].

The ability to perform FMS correctly (i.e. FMS proficiency/mastery) is associated with numerous health benefits and is important for the holistic development of children; including physical, psychological and overall well-being.[6] Among children, FMS proficiency has been shown to be positively associated with higher levels of PA,[11] physical fitness,[6,12] cognitive functioning and academic performance.[13] It has also been found to be inversely associated with weight status.[5,6] Furthermore, longitudinal data has revealed that FMS proficiency tracks through childhood[14,15] into adolescence[16,17] and is a significant predictor of adolescent PA.[18]

Although children have the potential to master FMS by the age of seven[1] and despite the early years being highlighted as a critical period in the development of FMS,[9] many studies report less than satisfactory levels of FMS proficiency among primary school aged children (age range: 4-13 years).[19–27]

As childhood obesity and physical inactivity are serious global health challenges in the 21st century,[28,29] the area of movement skill proficiency among children has received much interest internationally as a potential mechanism to combat these global problems.[11] Several systematic reviews have been conducted reporting (i) the effectiveness of FMS skill interventions in improving FMS proficiency in youth,[30] (ii) the relationship between FMS and PA in children and adolescents[11] and (iii) the effects of fundamental movement skill interventions on health outcomes.[31] To date, no study has attempted to collate the FMS proficiency levels of primary school aged children worldwide, to provide a global overview. To enable meaningful comparison of FMS proficiency between studies, a sole focus on one FMS measurement tool is required, e.g. Test of Gross Motor Development-2 (TGMD-2).[32] Therefore, the aim of the current study was to conduct a systematic review of FMS proficiency levels of typically developing primary school aged children worldwide, measured via the TGMD-2.[32]

4.3 Methods

This review was conducted and reported in adherence to the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement.[33]

Systematic Search

Studies were identified by searching electronic databases and scanning reference lists of included articles. Seven electronic databases were searched: Medline [OVID], Sports Discus, ScienceDirect, ERIC, Scopus, PubMed and PsychInfo. The search was limited to studies from January 2003 so as to examine recent and relevant studies (i.e. over the last 15 years). The last search was conducted on February 4th, 2018. Search terms were divided into three different categories: (i) fundamental movement skill*, motor skill*, motor development, (ii) child*, youth, boy*, girl*, schoolchild* and (iii) TGMD-2, Test of

Gross Motor Development. The Boolean phrase 'AND' was used between categories and the associated phrase 'OR' was used within the phrase in each category.

Eligibility Criteria

Typically developing children of primary school age (4-13 years) were included. Studies involving the comparison of children from special populations (i.e. overweight/obese, those with disorders/disabilities) to a typically developing comparison group were not included. Studies from disadvantaged areas or low socioeconomic status were also excluded. Study designs included were randomized controlled trials (RCTs) using experimental and quasi-experimental design, observational/cross-sectional studies and pre-post trials. In studies where interventions/treatments were administered, only baseline findings were included. Studies were excluded if they met any of the following criteria: (i) included groups from specific populations (e.g. children from low socioeconomic status, those with disabilities/disorders, specific sports groups, etc.), (ii) participants were not primary school aged children, (iii) not published in a peer-reviewed journal, (iv) not published in English, (v) book chapters, case studies, dissertations, conference abstracts, review articles, meta-analyses, systematic reviews, protocol papers or editorials and (vi) full-text was not available.

Outcome Measures – TGMD-2

Only studies which used the TGMD-2 to assess FMS proficiency,[32] including translated versions, were included. Studies which scored FMS performances retrospectively (based on video recordings) or live on-site were reviewed.

The TGMD-2 is a criterion and norm-referenced process-oriented FMS assessment tool. Normative sample data is provided in the TGMD-2, which was collected from 1208 children from 10 states in the United States between 1997 and 1998.[32] This facilitates the comparison of FMS proficiency to a standardisation sample.

The TGMD-2 consists of 12 FMS, divided into two subsets of skills; locomotor and object-control. The six locomotor skills assessed are the run, gallop, slide, leap, hop and horizontal jump. The six object-control skills assessed are the kick, catch, overhand throw, strike, underhand roll and dribble.[32] It has been found to be valid and reliable among children aged three to 10 years.[32] Content validity was established qualitatively, based on unanimous agreement of three content experts who declare the skills as representative of those taught to the specified age group and also quantitatively, using discrimination and item difficulty statistics. Criterion-prediction validity of the TGMD-2 is reported, with a strong to moderate correlation between TGMD-2 subtests and criterion variable (ranging from .43 - .63). Construct validity has also been established.[32] Internal consistency reliability of the subsets, assessed using Cronbach alpha, ranged from .85 (locomotor subset) to .88 (object-control subset). The reliability coefficient for GMQ, assessed using Guilford's formula, was found to be .91.[32] The TGMD-2 also has high test-retest reliability (ranging from .88 - .93) and inter-rater reliability (.98 for all) across subsets and GMQ.[32]

In this assessment tool, children perform one familiarisation trial and two test trials. Each of the 12 FMS consist of 3-5 behavioural components. If a component is performed correctly, a score of 1 is awarded. If the behavioural component is performed incorrectly, a score of 0 is awarded. This procedure is repeated for each component of a skill across the two test trials. Scores from both trials are summed to obtain a raw skill score.[32] 'Mastery' of an FMS is achieved when all components of a skill are present (i.e. skill performed correctly) across both test trials.

Locomotor and object-control subset scores are calculated by summing the raw scores of the individual skills within each subset (Locomotor Score Range: 0-48; Object-control Score Range: 0-48). Subset scores are converted, to standard scores (LSS and OCSS, range: 1-20), using conversion tables based on age and sex as outlined in the TGMD-2.[32] The combined LSS and OCSS score is converted (as outlined in the TGMD-2 conversion tables), based on age and sex, to an overall FMS proficiency score or Gross Motor Quotient (GMQ; range: 48-160). LSS, OCSS and GMQ can be used to categorise the locomotor, object-control and overall FMS performance of each child into one of seven categories, ranging from *very poor* to *very superior*.[32] Children with a standard score (LSS/OCSS) between 1-3 are classified as *very poor*, between 4-5 classified as *poor*, 6-7 as *below average*, 8-12 as *average*, 13-14 as *above average*, 15-16 as *superior* and 17-

20 as *very superior* in terms of locomotor/object-control proficiency.[32] Using GMQ, overall FMS proficiency of children are also classified based on score ranges (*very poor*: <70; *poor*: 70-79; *below average*: 80-89; *average*: 90-110; *above average*: 111-120; *superior*: 121-130; *very superior*: >130).[32]

Analysis of data collected using the TGMD-2 can also be used to derive mean percentiles and age equivalents. Mean percentiles, or percentile rank, represent the proportion of the normative sample who achieved a value equal to or below the associated score. For example, a percentile of 60 means that 60% of the normative sample scored less than or equal to the performer's score. Age equivalents use subset scores to provide an estimated developmental age based on a child's performance.[32]

In the current review, studies were included if they reported ≥1 of the following outcome measures: raw score (either subset, in ≥1 skill or total), standard score (subset or total), gross motor quotient (GMQ), mean percentile (subset or overall), the percentage of the sample achieving mastery (in ≥1 skill), the proportion of children classified into each of the TGMD-2 performance categories, ranging from *very poor* to *very superior* (for locomotor, object-control or overall proficiency). Only studies that provided numerical data/findings were included (i.e. graphs/charts without numerical labels were not).

Study Selection

Following the systematic search, two reviewers (LEB and LAB) independently removed all duplicates and the title and abstract of the remaining retrieved files were screened. Any disagreements were resolved by reviewing articles together and through discussion. Full-text articles were retrieved for the remaining files and independently screened by both reviewers for inclusion criteria, using a 'yes, no or maybe' approach.[34] Level of agreement was found to be 93%. Conflicting decisions (including files assigned 'maybe') were jointly reviewed together and discussed until consensus was reached on all files.

Overview of Studies

Figure 4.1 displays the PRISMA flowchart of studies through the review process. The search strategy identified 933 records. After removing duplicates (*n*=281) and screening of titles and abstracts (*n*=652), 76 articles were retrieved. Of these, 33 fulfilled the inclusion criteria and were included.

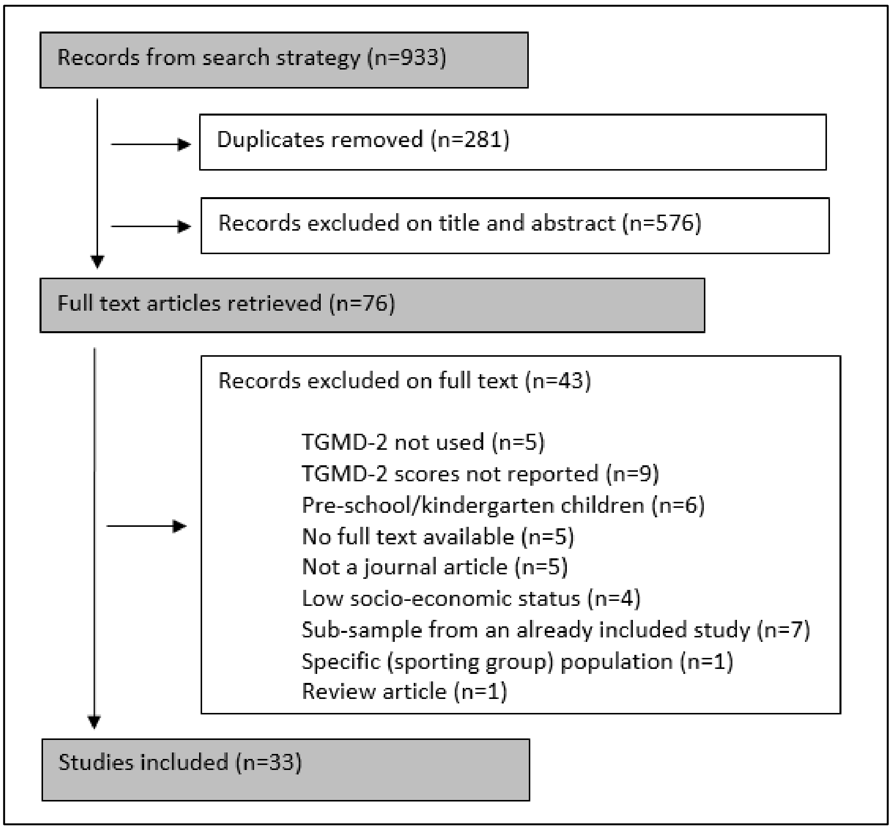

Figure 4.1: PRISMA flowchart of studies through the review process

Data Extraction

The following data were independently extracted by two reviewers (LEB and LAB) using an Excel template developed by both reviewers: (i) author and year of publication, (ii) research design and setting, (iii) participant characteristics (including age, sex, country, sample size, specifics of population group), (iv) the number of FMS assessed and administration protocol used (i.e. individually or in groups), (v) FMS scoring protocol (including live/retrospective scoring, inter-/intra-rater reliability) and (vi) type of outcome measure reported (raw skill/subset scores, standard score, GMQ, percentage achieving mastery in each skill, age equivalent score, mean percentile). Data extracted independently by both reviewers were compared, with 100% agreement found.

Data Extraction

Data (excluding actual FMS outcome scores) were first collated and described in a narrative summary. FMS outcome scores (i.e. FMS levels) from each study were quantitatively reported (in the form of raw scores, standard scores, age equivalent, mean percentiles, percentage achieving mastery in each skill or percentage categorised across TGMD-2 categories). In studies that assessed the FMS levels of children from of a wide age range, which also include children of ages outside of those outlined in the inclusion criteria (4-13 years), data was excluded if reported by individual age for the age groups which do not meet the inclusion criteria (e.g. 3-year-olds). However, when included as part of an age range (e.g. 3-10 years), data were included and reported with an asterisk (*).

Data Analysis

Mean and standard deviation scores of each FMS outcome score reported in each study were included. As evidence reveals older children tend to exhibit superior FMS proficiency than younger children,[19,21,22,27,35] FMS outcome scores were collated for each individual age ranging from 4-13 years of age, the younger age range (4-8 years), the older age range (8-13 years) and overall primary school age children (4-13 years).

For each group, weighted mean and standard deviation scores were calculated for raw FMS scores (skill, subset and total), standardised scores (GMQ, SS) and percentile scores (subset and overall rank) using the following formulas[36]:

Weighted mean $(\overline{x_w})$ = $\dfrac{\sum(w_i * x_i)}{\sum w_i}$

Weighted standard deviation (sd_w) = $\sqrt{\dfrac{\sum_{i=1}^{N} w_i(x_i - \overline{x_w})^2}{\dfrac{(N'-1)\sum_{i=1}^{N} w_i}{N'}}}$

where w_i is the weight of the i^{th} observation (i.e. sample size), x_i is the mean score of the i^{th} observation, N' is the number of non-zero weights.[36]

The weighted frequency of children achieving mastery in each of the 12 FMS and the frequency of children in each of the TGMD-2 categories (for LOCO, OC and overall proficiency) were calculated using the following equation:

$$\text{Weighted frequency} = \frac{\sum_{i=1}^{N} Frenquency_i}{\sum n}$$

where $frequency_i$ is the number of children achieving mastery (or present in a category) in the i^{th} observation and n is the sample size.

Study Quality Assessment

Study quality was independently assessed by two reviewers (LEB and LAB) using the Study Quality Assessment Tools developed by the National Heart, Lung and Blood Institute.[37] Three appropriate tools were used: (i) Quality Assessment of Controlled Intervention Studies, (ii) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies and (iii) Quality Assessment Tool for Before-After (Pre-Post) Studies With No Control Group (Tables 4.1-4.3). Each item on the scale was coded as '1' (Yes), '0' (No), 'CD' (cannot determine), 'NR' (not reported) or 'NA' (not applicable). Each item was individually considered, as recommended by the PRISMA statement.[33] Inter-rater reliability between reviewers was calculated, with >85% agreement established across all 460 items. Following this review process, articles in which disagreements were found were further reviewed by both assessors together and following discussion, consensus was reached.

Table 4.1: Quality Assessment Checklist for Cross-Sectional Studies

	Antunes et al[42]	Bardid et al[19]	Barnett et al[44]	Butterfield et al[53]	Cano-Cappellacci et al[41]	Cepicka[62]	De Meester et al[40]	Du Plessis et al[51]	Freitas et al[35]	Grant-Beuttler et al[49]	Khodaverdi et al[47]	Kim et al[46]	Lin & Yang[45]	Liong et al[44]	Logan et al[43]	Mukherjee et al[55]	Palmer et al[38]	Pang & Fong[8]	Pienaar et al[60]	Robinson et al[59]	Rudd et al[57]	Slykerman et al[56]	Spessato et al[27]	Spessato et al[52]	Valentini[64]	Wong & Cheung[66]	Zuvela et al[63]
Was the research question or objective in this paper clearly stated?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Was the study population clearly specified and defined?	1	1	0	0	1	0*	0*	1	1	0	1	0*	0*	0*	0*	0*	0*	0*	1	0	0*	1	0*	0*	0*	1	0*
Was the participation rate of eligible persons at least 50%?	0	NR	0	NR	0	NR	NR	1	NR	NR	0	NR	NR	0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0
Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants?	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	Antunes et al[42]	Bardid et al[19]	Barnett et al[44]	Butterfield et al[53]	Cano-Cappellacci et al[41]	Cepicka[62]	De Meester et al[40]	Du Plessis et al[51]	Freitas et al[35]	Grant-Beuttler et al[49]	Khodaverdi et al[47]	Kim et al[46]	Lin & Yang[45]	Liong et al[44]	Logan et al[43]	Mukherjee et al[55]	Palmer et al[38]	Pang & Fong[8]	Pienaar et al[60]	Robinson et al[59]	Rudd et al[57]	Slykerman et al[56]	Spessato et al[27]	Spessato et al[52]	Valentini[64]	Wong & Cheung[66]	Zuvela et al[63]
Was a sample size justification, power description, or variance and effect estimates provided?	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	CD	0	0	0	0	0	0	0
Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

	Antunes et al[42]	Bardid et al[19]	Barnett et al[44]	Butterfield et al[53]	Cano-Cappellacci et al[41]	Cepicka[62]	De Meester et al[40]	Du Plessis et al[51]	Freitas et al[35]	Grant-Beuttler et al[49]	Khodaverdi et al[47]	Kim et al[46]	Lin & Yang[45]	Liong et al[44]	Logan et al[43]	Mukherjee et al[55]	Palmer et al[38]	Pang & Fong[8]	Pienaar et al[60]	Robinson et al[59]	Rudd et al[57]	Slykerman et al[56]	Spessato et al[27]	Spessato et al[52]	Valentini[64]	Wong & Cheung[66]	Zuvela et al[63]
Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	1	NA	NA	NA	NA	NA	NA	NA
Was the exposure(s) assessed more than once over time?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Were the outcome assessors blinded to the exposure status of participants?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	1	NA	NA	NA	NA	NA	NA	NA
Was loss to follow-up after baseline 20% or less?	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	NA	NA	NA	NA

	Antunes et al[42]	Bardid et al[19]	Barnett et al[44]	Butterfield et al[53]	Cano-Cappellacci et al[41]	Cepicka[62]	De Meester et al[40]	Du Plessis et al[51]	Freitas et al[35]	Grant-Beuttler et al[49]	Khodaverdi et al[47]	Kim et al[46]	Lin & Yang[45]	Liong et al[44]	Logan et al[43]	Mukherjee et al[55]	Palmer et al[38]	Pang & Fong[8]	Pienaar et al[60]	Robinson et al[59]	Rudd et al[57]	Slykerman et al[56]	Spessato et al[27]	Spessato et al[52]	Valentini[64]	Wong & Cheung[66]	Zuvela et al[63]
Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0

*denotes study population was clearly defined and specified but the time period at which assessment was conducted were not reported

1 :Yes, 0: No, CD: cannot determine, NR: not reported, NA: not applicable

Table 4.2: Quality Assessment Checklist for Pre-Post Study Designs

	Burrows et al[53]	Capio et al[54]
Was the study question or objective clearly stated?	1	1
Were eligibility/selection criteria for the study population pre-specified and clearly described?	1	1
Were the participants in the study representative of those who would be eligible for the test/service/intervention in the general or clinical population of interest?	1	1
Were all eligible participants that met the pre-specified entry criteria enrolled?	0	1
Was the sample size sufficiently large to provide confidence in the findings?	NR	NR
Was the test/service/intervention clearly described and delivered consistently across the study population?	1	1
Were the outcome measures pre-specified, clearly defined, valid, reliable, and assessed consistently across all study participants?	1	1
Were the people assessing the outcomes blinded to the participants' exposures/interventions?	NR	0
Was the loss to follow-up after baseline 20% or less? Were those lost to follow-up accounted for in the analysis?	1	1
Did the statistical methods examine changes in outcome measures from before to after the intervention? Were statistical tests done that provided p values for the pre-to-post changes?	1	1
Were outcome measures of interest taken multiple times before the intervention and multiple times after the intervention (i.e., did they use an interrupted time-series design)?	0	0
If the intervention was conducted at a group level (e.g., a whole hospital, a community, etc.) did the statistical analysis take into account the use of individual-level data to determine effects at the group level?	1	1

1 :Yes, 0: No, CD: cannot determine, NR: not reported, NA: not applicable

Table 4.3: Quality Assessment Checklist for Intervention Studies

	Bakhtiari et al[65]	Johnstone et al[48]	Miller et al[39]	Rudd et al[58]
Was the study described as randomized, a randomized trial, a randomized clinical trial, or an RCT?	0	0	1	0
Was the method of randomization adequate (i.e., use of randomly generated assignment)?	NR	0	1	0
Was the treatment allocation concealed (so that assignments could not be predicted)?	NR	0	1	0
Were study participants and providers blinded to treatment group assignment?	NR	NR	NR	NR
Were the people assessing the outcomes blinded to the participants' group assignments?	NR	NR	1	1
Were the groups similar at baseline on important characteristics that could affect outcomes (e.g., demographics, risk factors, co-morbid conditions)?	1	1	1*	1
Was the overall drop-out rate from the study at endpoint 20% or lower of the number allocated to treatment?	1	1	1	1
Was the differential drop-out rate (between treatment groups) at endpoint 15 percentage points or lower?	1	1	1	1
Was there high adherence to the intervention protocols for each treatment group?	NR	NR	1	1
Were other interventions avoided or similar in the groups (e.g., similar background treatments)?	NR	1	NR	NR
Were outcomes assessed using valid and reliable measures, implemented consistently across all study participants?	1	1	1	1
Did the authors report that the sample size was sufficiently large to be able to detect a difference in the main outcome between groups with at least 80% power?	0	0	1	0
Were outcomes reported or subgroups analyzed prespecified (i.e., identified before analyses were conducted)?	1	1	1	1
Were all randomized participants analyzed in the group to which they were originally assigned, i.e., did they use an intention-to-treat analysis?	1	1	1	1

*denotes similar age, socio-economic status, and OC proficiency but differences between catch proficiency and in-class PA levels

1 :Yes, 0: No, CD: cannot determine, NR: not reported, NA: not applicable

4.4 Results

Study Characteristics

Table 4.4 presents the selected characteristics of eligible studies included in this review. Twenty-six studies were published between 2013 and 2018,[19,27,35,38–60] six between 2008 and 2012[8,61–65] and one between 2003 and 2007.[66] Studies selected for inclusion were drawn from 15 different countries across six continents. Six studies were carried out in the United States,[38,40,43,49,59,61] five in Australia, [39,44,56–58] four in Brazil,[27,52,64,67] three in China,[8,54,66] two in South Africa,[51,60] Portugal,[35,42] and Iran[47,65] and one in Canada,[53] Croatia,[63] Singapore,[55] Czech Republic,[62] Chile,[41] Belgium,[19] Taiwan,[45] South Korea[46] and Scotland.[48] The majority of studies (24 of 33: 73%) involved the evaluation of FMS of children recruited from a primary school setting,[8,27,35,39,41–45,47,48,50,51,54–58,60–65] including three that were recruited specifically in public primary schools,[43,47,52] one from a rural primary school[61] and one from an urban primary school.[62] Two separate studies recruited from a summer enrichment programme on a university campus including primary school-aged children.[38,59] One study recruited from 51 child settings including sports clubs, local councils, school and day-care centres.[19] One study recruited from a before/after school programme as well as from an urban and rural primary school,[40] one from an after-school programme,[53] one from Kindergarten and YMCA Hong Kong Summer Camp[66] and one from public schools as well as day-care centres.[27] Another recruited by distributing flyers to the local school district, at professional meetings and given to friends of participants,[49] while two studies did not report how children were recruited.[46,57]

There were 24 cross-sectional design studies,[8,19,27,35,38,40–47,49,50,52,55–57,59,61,62,64,66] five quasi-experimental studies,[48,53,54,58,65] one cluster RCT[39] and one study which was a construction and validation of a new FMS tool.[63] Two studies were part of a longitudinal study, the 'North-West-CHILD Study',[51,60] one which reported the baseline findings[51] and another the follow-up findings at three years, which also included newly recruited children.[60] The sample sizes for the studies ranged from 40[53,65] to 2674 children.[64] Eleven studies had a sample size between 100-199 children[8,39,42,44,46,48,50,52,56,57,61] while 14 had a sample size >200.[19,27,35,40,45,47,51,54,55,58,60,62,64,66] Two studies included girls only,[47,65] one did not specify if children from both sexes were included,[46] while the remaining were co-educational.

Measurement of FMS

Twenty-six studies tested all 12 skills of the TGMD-2,[8,19,27,35,40–49,52,53,55–59,63,65,66] four studies tested the six OC skills only,[38,50,51,60] one study examined three OC skills (throw, catch, kick),[39] one study examined four OC skills only (throw, catch, kick, strike)[61] and one study solely examined the throw.[54] Thirteen studies did not report whether FMS performances were scored/coded live or retrospectively using video recordings.[35,40,42,44,48,51,56,58,60–63,65] Of the 20 studies which did specify, 17 coded FMS performances retrospectively[8,27,38,39,41,43,45–47,49,52,53,55,57,59,64,66] while three coded assessments live on site.[19,50,54] The number of individuals who scored or coded the

FMS performances of participants (i.e. coders) ranged from one[8,38,39,59,66] to four.[45,54] The use of two coders was the most commonly reported scoring protocol selected,[27,41,43,44,47,49,50,53,57,58,60,61,68] while three studies required three coders.[46,52,64] The remaining 11 did not report the number of coders used.[19,35,40,42,48,51,55,56,62,63,65] In seven of the studies, assessments were conducted individually.[19,27,40,42,49,59,64] Six studies conducted the assessments in small groups, ranging from 2-6 children,[41,43,44,49,53,57,58] while the majority (*n*=20) did not specify.[8,35,38,39,45–48,50–52,54–56,60–63,65,66]

FMS Outcomes

Raw scores (skill scores and subset scores) were the most reported type of FMS outcome, with 20 studies reporting OC subset score,[8,19,35,38,41,42,44–47,50,53,55–59,62,64,66] 18 reporting LOCO subset score[8,19,35,41,42,44–47,53,55–59,62,64,66] (Table 4.5) and 12 reporting individual raw skills scores [19,35,38,39,42,45,46,51,54,60,61,64] (Table 4.6). Raw total FMS score was less commonly reported, which was included in five studies[44,45,52,55,63] (Table 4.5). Standardised scores based on age and sex, including GMQ[8,19,43,47–49,53,55] and OC SS[19,43,48,49,55,60,65] were reported by eight studies, while LSS were reported by seven studies.[8,19,43,48,49,55,65] Total SS (which is subsequently used to calculate GMQ) was reported in two studies[8,55](Table 4.7).

Five studies reported overall percentile rank[8,40,48,55,65] and mean OC percentile,[8,48,55,60,62] with four studies reporting mean LOCO percentile.[8,48,55,62] Mukherjee et al.[55], Spessato et al.[27] and Pang and Fong[8] reported age equivalent scores for both LOCO and OC proficiency, with Pineaar et al.[60] also reporting mean OC percentile (Table 4.7). The proportion of children classified into the seven TGMD-2 categories based on proficiency was reported in two studies for LOCO,[8,19] three studies for OC[8,19,60] and four studies for GMQ[8,19,52,55] (Table 4.8). The mastery levels (percentage of children achieving mastery) in each of the 12 FMS were reported by three studies[55,61,66] (Table 4.9).

Table 4.4: Study characteristics

Authors	Country	Design**	Setting	Sample					L/R***	No. per group for test	Coders (n)	>85% Reliability		FMS Tested	Scores reported
				n	Boys	Girls	Age (M: Mean)	Population information				Inter-rater	Intra-rater		
Antunes et al[42]	Portugal	CS	Primary school	158	83	75	6-8	Sub-sample of original study (Healthy Growth of Madeira Study)	NR	1	NR	NR	NR	12	Subset Scores (and selected FMS)
Bakhtiari et al[65]	Iran	QE: Semi-experimental	Elementary school	40 EXP: 20 CON: 20	0	40 EXP: 20 CON: 20	9 EXP: 8.9 (.49) CON: 8.9 (.48)	Third grade girls from elementary school in Ahvaz	NR	NR	NR	NR	NR	12	SS (LOCO, OC) Overall Percentile Rank
Bardid et al[19]	Belgium	CS	51 child settings including sports clubs, local councils, schools and day-care centres	1614	841	773	3-8*	51 settings (sports clubs, local councils, schools, day care centres) from all 5 Flemish provinces and Brussels Capital Region	L	1	NR	NR	NR	12	Raw Subset Scores (LOCO, OC) Raw Skill Scores (12 FMS) SS (LOCO, OC) GMQ Distribution across TGMD-2 categories (LOCO, OC, GMQ)
Barnett et al[44]	Australia	CS	Primary school	102	57	45	4-8 M: 6.3 (.92)	3 primary schools - first 3 year levels	L	NR	2	Yes	NR	6 OC	Raw Subset Score (OC)

Authors	Country	Design**	Setting	Sample					L/R***	No. per group for test	Coders (n)	>85% Reliability		FMS Tested	Scores reported
				n	Boys	Girls	Age (M: Mean)	Population information				Inter-rater	Intra-rater		
Burrows et al[53]	Canada	QE	Primary school: After-school programme	40 Games: 25 Sports: 15	17 Games: 9 Sports: 8	23 Games: 16 Sports: 7	Games: 7.64 (1.06) Sports: 8.05 (1.08)	2 after-school programmes: 1 low-organized games programme 1 sports-based programme activity	R	2	2	Yes	NR	12	Raw Subset Scores (LOCO, OC) GMQ
Butterfield et al[61]	US	CS	Rural primary school	186	105	81	5-14 M: 9.6 (2.5) Boys: 10.0 (2.4) Girls: 9.1 (2.5)	Grades K-8	NR	NR	2	Yes	NR	4 OC: Catch Throw Kick Strike	Raw Skill Scores (4 OC) Mastery Levels
Cano-Cappellacci et al[41]	Chile	CS: validation & reliability study	Primary school	92	56	36	5-10 M: 7.5 (1.6)		R	3	2	Yes	Yes	12	Raw Subset Scores (LOCO, OC)
Capio et al [54]	China	QE	Primary school	216 Error-reduced (ER): 99 Error-strewn (ES): 117	109 ER: 50 ES: 59	107 ER: 49 ES: 58	8-12 M: 9.16 (.96)	2 training programmes assigned: Error-reduced (ER) Error-Strewn (ES)	L	NR	4	Yes	NR	1: Throw	Raw Skill Score
Cepicka[62]	Czech Republic	CS	Urban elementary schools	315	152	163	Boys: 7.1 (.3) Girls: 7.0 (.3)	Grade 1	NR	NR	NR	NR	NR	12	Raw Subset Scores (LOCO, OC) Mean Percentiles (LOCO, OC)

Authors	Country	Design**	Setting	Sample					L/R***	No. per group for test	Coders (n)	>85% Reliability		FMS Tested	Scores reported
				n	Boys	Girls	Age (M: Mean)	Population information				Inter-rater	Intra-rater		
De Meester et al[40]	US	CS	Urban school, rural school, before and after school program	361	180	181	6.92-11.83 M: 9.50 (1.24)	Urban school district in Ohio, rural school in Texas, before and after school programme in Michigan	NR	1	NR	NR	NR	12	Overall Percentile Rank
Du Plessis et al[51]	South Africa	Randomised longitudinal: Baseline	Primary school	806	413	393	6.84 (.39)	Baseline data of NW-CHILD longitudinal study (Grade 1 - 20 schools from 4 districts)	NR	NR	NR	NR	NR	6 OC	Raw Skill Scores (6 OC skills)
Freitas et al[35]	Portugal	CS	Primary school	429	213 7y: 48 8y: 51 9y: 45 10y: 69	216 7y: 45 8y: 41 9y: 52 10y: 78	7-10 Boys 7y: 7.5 (.3) Boys 8y: 8.5 (.3) Boys 9y: 9.5 (.3) Boys 10y: 10.6 (.3) Girls 7y: 7.5 (.3) Girls 8y: 8.5 (.3) Girls 9y: 9.4 (.3) Girls 10y: 11.0 (1.4)	40 schools randomly selected from the 11 districts of Madeira and Porto Santo	NR	NR	NR	NR	NR	12	Raw Skill Scores Raw Subset Scores (LOCO, OC)
Grant-Beuttler et al[49]	US	CS	Flyers posted at local school districts, at professional meetings and given to friends of participants, between 4-9years	54 4y: 9 5y: 9 6y: 9 7y: 9 8y: 9 9y: 9	27 4y: 4 5y: 5 6y: 4 7y: 5 8y: 5 9y: 4	27 4y: 5 5y: 4 6y: 5 7y: 4 8y: 4 9y: 5	4-10 4y: 4.5 (.4) 5y: 5.7 (.2) 6y: 6.4 (.2) 7y: 7.5 (.2) 8y: 8.2 (.2) 9y: 9.7 (.3)	Flyers posted at local school districts, at professional meetings and given to friends of participants, between 4-9 years	R	1	2	NR	NR	12	GMQ SS (LOCO, OC)

Authors	Country	Design**	Setting	Sample					L/R***	No. per group for test	Coders (n)	>85% Reliability		FMS Tested	Scores reported
				n	Boys	Girls	Age (M: Mean)	Population information				Inter-rater	Intra-rater		
Johnstone et al[48]	Scotland	QE: Pragmatic evaluation	Primary school	123 INT: 102 CON: 21	90 INT: 82 CON: 8	106 INT: 90 CON: 16	Grade 1-5	7 primary schools involving classes from grades 1-5 (INT), grades 2-4 (CON)	NR	NR	NR	NR	NR	12	GMQ Overall Percentile Rank SS (LOCO, OC) Mean Percentile (LOCO, OC)
Khodaverdi et al[47]	Iran	CS	Public primary schools	352	0	352	8-9 M: 8.78 (.32)	Public primary schools located in the urban southwestern part of Tehran Province (3rd Grade)	R	NR	2	Yes	NR	12	Raw Subset Scores (LOCO, OC) GMQ
Kim et al[46]	South Korea	CS: validation & reliability study	NR	139			3-10* M: 6.8 (1.9)	Southeast region of Seoul, 3 of the 25 boroughs of Seoul	R	NR	3	Yes	NR	12	Raw Subset Scores (LOCO, OC) Raw Skill Scores
Lin & Yang[45]	Taiwan	CS	Elementary school	485 6-7y: 92 7-8y: 197 8-9y: 196	244	241	6-9 M: 7.67	From Chiayi City and Chiayi County	R	NR	4	Yes	NR	12	Raw Skill Scores Raw Subset Scores (LOCO, OC) Raw Total Score
Liong et al[44]	Australia	CS	Primary school	136	70	66	5-8 M: 6.5 (1.1)	2 elementary schools	NR	2-3	2	Yes	NR	12	Raw Subset Scores (LOCO, OC) Raw Total Score

Authors	Country	Design**	Setting	Sample					L/R***	No. per group for test	Coders (n)	>85% Reliability		FMS Tested	Scores reported
				n	Boys	Girls	Age (M: Mean)	Population information				Inter-rater	Intra-rater		
Logan et al[43]	US	CS	Public elementary school	67 Kindergarten (K): 20 Grade 1: 22 Grade 2: 23	32 K: 10 Grade 1: 13 Grade 2: 9	33 K: 10 Grade 1: 9 Grade 2: 14	K: 5.7 (.38)* Grade 1: 6.7 (.34) Grade 2: 7.8 (.46)	Southeast region of the US	R	3-5	2	Yes	Yes	12	SS (LOCO, OC) GMQ
Miller et al[39]	Australia	Cluster RCT	Primary school	168 INT: 97 CON: 71	72 INT: 38 CON: 34	96 INT: 59 CON: 37	INT: 11.12 (1.28) CON: 11.20 (.61)	7 primary schools	R	NR	1	Yes	Yes	3 OC: Throw Catch Kick	Raw Skill Score
Mukherjee et al[55]	Singapore	CS	Primary school	244 Primary 1 (P1): 120 Primary 3 (P3): 124	132 P1: 60 P3: 72	112 P1: 60 P3: 52	P1: 6-7.5 P3: 8-10	4 government-aided primary schools	R	NR	NR	Yes	Yes	12	Raw Subset Scores (LOCO, OC) Raw Total Score SS (Loco, OC) Mean Percentile (LOCO, OC) Age Equivalent (LOCO, OC) Percentile rank (Overall) GMQ Distribution across GMQ categories Mastery Levels (12 skills)

Authors	Country	Design**	Setting	Sample					L/R***	No. per group for test	Coders (n)	>85% Reliability		FMS Tested	Scores reported
				n	Boys	Girls	Age (M: Mean)	Population information				Inter-rater	Intra-rater		
Palmer et al[38]	US	CS	Summer enrichment programme on a university campus	44	20	24	5-10 M: 7.7	Summer enrichment programme on a university campus in southern region of US	R	NR	1	Yes	NR	6 OC	Raw Skill Score (6 OC skills) Raw Subset Score (OC)
Pang & Fong[8]	China	CS	Primary school	167	91	76	6-9 M:7.6 (.9)	6 primary schools in Hong Kong	R	NR	1	Yes	Yes	12	Raw Subset Scores (LOCO, OC) Mean Percentiles (LOCO, OC) SS (LOCO, OC, TOTAL) Age Equivalent (LOCO, OC) GMQ GMQ Percentile Distribution across LOCO, OC and GMQ Categories

Authors	Country	Design**	Setting	Sample					L/R***	No. per group for test	Coders (n)	>85% Reliability		FMS Tested	Scores reported
				n	Boys	Girls	Age (M: Mean)	Population information				Inter-rater	Intra-rater		
Pienaar et al[60]	South Africa	Randomised longitudinal: Follow-up 1	Primary school	826	433	393	9.9 (.63)	First follow-up group of the NW-CHILD study: From 4 out of 8 educational districts in the North West province of South Africa, representing 5 different school quintiles; Grade 3 and 4 children	NR	NR	2	Yes	NR	6 OC	Raw Skill Scores (OC skills) OC Age Equivalent OC Mean Percentile OC SS Distribution across GMQ OC Categories
Robinson et al[59]	US	CS	Summer enrichment programme on a university campus from public school	45 Younger: 21 Older: 24	21 Younger: 12 Older: 9	24 Younger: 9 Older: 15	5-10 Younger: 5.95 (.80) Older: 8.96 (.86)	Summer enrichment programme on a university campus from a southeastern public school	R	1	1	Yes	NR	12	Raw Subset Scores (LOCO, OC)
Rudd et al[57]	Australia	CS	NR	158	86	72	6-12 M: 9.5 (2.2)	6-8years 8-10years 10-12years	R	4	2	Yes	NR	12	Raw Subset Scores (LOCO, OC)
Rudd et al[58]	Australia	QE	Primary school	333 INT: 135 CON: 198	171 INT: 69 CON: 102	162 INT: 66 CON: 96	M: 8.1 (1.1)	Grade 1-4 of 3 primary schools: 1 low, medium, high SES school	NR	5	2	Yes	NR	12	Raw Subset Scores (LOCO, OC)
Slykerman et al[56]	Australia	CS	Primary school	109	59	50	5-8 M: 6.5 (1.0)	2 primary schools in Victoria	NR	NR	NR	Yes	NR	12	Raw Subset Scores (LOCO, OC)

Authors	Country	Design**	Setting	Sample					L/R***	No. per group for test	Coders (n)	>85% Reliability		FMS Tested	Scores reported
				n	Boys	Girls	Age (M: Mean)	Population information				Inter-rater	Intra-rater		
Spessato et al[27]	Brazil	CS	Public schools & daycare centres	1248 3-4y: 212 5-6y: 348 7-8y: 326 9-10y: 362	641 3-4y: 109 5-6y: 175 7-8y: 177 9-10y: 180	607 3-4y: 103 5-6y: 173 7-8y: 149 9-10y: 182	3-10* 3-4y: 4.0 (.5) 5-6y: 6.1 (.6) 7-8y: 8.0 (.6) 9-10y: 9.8 (.5)	50 public schools and daycare centres in large metropolitan city, South Brazil	R	NR	2	Yes	NR	12	Age Equivalent (LOCO, OC)
Spessato et al[52]	Brazil	CS	Public schools	178	82	96	4-7 M: 5.36 (1.0)	8 Public schools in Rio Grande do Sul	R	1	3	NR	NR	12	Raw Total Score Distribution across GMQ categories
Valentini[64]	Brazil	CS: validation & reliability study	Primary school	2674	1352	1322	3-10* M: 7.56 (1.91)	Schools from 15 cities from 10 states (2 states from each region) in Brazil	R	1	3	Yes	Yes	12	Raw Subset Scores (LOCO, OC) Raw Skill Scores
Wong & Cheung[66]	China	CS	Kinder-gartens and 2005 YMCA of Hong Kong Summer Camp	1228	675	553	3-10* M: 6.45 (2.10)	4 Kindergartens and 2005 YMCA of Hong Kong Summer Camp	R	NR	1	Yes	NR	12	Raw Subset Scores (LOCO, OC) Mastery Levels for indivdual skills
Zuvela et al[63]	Croatia	Construction and validation of new FMS tool	Elementary school	95	48	47	8.1 (.3)	Randomly selected from 300 children from 3 schools	NR	NR	NR	NR	NR	12	Raw Total Score

*includes children outside 4-13y age range; **QE: Quasi-experimental, CS: Cross-sectional; ***L: Live, R: Retrospective; LOCO: Locomotor; OC: Object-control; SS: Standard Score; GMQ: Gross Motor Quotient; INT: Intervention group, EXP: Experimental group, CON: Control group; ER: Error-reduced training groups; ES: Error-strewn training group; Games: Games intervention group; Sports: Sports intervention group; FMS: fundamental movement skills; TGMD-2: Test of Gross Motor Development-2; NR: Not reported

Table 4.5: Summary of the results of studies that reported raw subset FMS scores

	Age	n	Group	RAW		
				LOCO	OC	Total
Antunes et al[42]	6 (6.72 ± .2)	27	Boys	32.0 (5.8)	30.7 (5.2)	
	6 (6.64 ± .2)	23	Girls	30.8 (7.2)		
	7 (7.58 ± .2)	28	Girls	35.7 (3.7)		
	7 (7.62 ± .2)	29	Boys	35.4 (5.1)	32.8 (5.7)	
	8 (8.59 ± .3)	27	Boys	37.6 (4.1)	35.9 (3.9)	
	8 (8.68 ± .3)	24	Girls	37.7 (4.1)		
Bardid et al[19]	4	159	Girls	29.7 (6.9)	18.1 (5.3)	
	4	215	Boys	28.0 (8.1)	22.3 (6.0)	
	4	374		28.7 (7.6)	20.5 (6.1)	
	5	149	Girls	34.4 (6.0)	23.3 (5.6)	
	5	181	Boys	33.6 (6.3)	27.4 (6.4)	
	5	330		34.0 (6.2)	25.6 (6.4)	
	6	164	Girls	37.1 (5.6)	26.5 (5.8)	
	6	159	Boys	36.5 (5.6)	33.1 (6.4)	
	6	323		36.8 (5.6)	29.8 (7.0)	
	7	107	Girls	38.5 (4.9)	29.7 (6.1)	
	7	103	Boys	38.1 (4.8)	36.4 (5.6)	
	7	210		38.3 (4.9)	33.0 (6.7)	
	8	81	Girls	38.4 (4.2)	32.4 (5.2)	
	8	62	Boys	39.6 (5.3)	38.1 (4.6)	
	8	143		38.9 (4.7)	34.9 (5.7)	
Barnett et al[50]	4-8	57	Boys		33.8 (7.0)	
	4-8	45	Girls		28.4 (6.9)	
	4-8 (6.3 ± .92)	102			31.4 (7.5)	
Burrows et al[53]	7.64 ± 1.06	25	Games	36.48 (5.95)	30.24 (8.32)	
	8.05 ± 1.08	15	Sports	38.20 (5.66)	35.00 (7.56)	
Cano-Cappellacci et al.[41]	5	16				57.8 (10.1)
	6	15				65.2 (7.7)
	7	13				64.6 (8.2)
	8	17				68.9 (8.8)
	9	23				68.2 (5.9)
	10	8				65.5 (6.4)
	5-10	36	Girls			61.2 (9.1)
	5-10	56	Boys			68.2 (7.1)
	5-10 (7.5 ± 1.6)	92		34.7 (4.7)	33.1 (4.2)	65.5 (8.6)
Cepicka[62]	7.0 ± .3	163	Girls	37.18 (4.82)	27.29 (5.86)	
	7.1 ± .3	152	Boys	33.19 (5.26)	32.81 (5.39)	
Freitas et al[35]	7 (7.5 ± .3)	48	Boys	34.7 (5.1)	31.7 (5.8)	
	7 (7.5 ± .3)	45	Girls	36.0 (4.1)	28.6 (6.2)	
	8 (8.5 ± .3)	51	Boys	37.5 (3.8)	35.9 (4.1)	
	8 (8.5 ± .3)	41	Girls	37.8 (4.0)	29.0 (5.3)	
	9 (9.4 ± .3)	52	Girls	38.2 (3.9)	32.3 (4.7)	
	9 (9.5 ± .3)	45	Boys	39.2 (5.6)	37.0 (5.8)	
	10 (10.6 ± .3)	69	Boys	39.3 (4.7)	39.9 (4.6)	
	10 (10.6 ± .3)	78	Girls	40.0 (4.1)	34.7 (5.8)	

Khodaverdi et al[47]	8-9 (8.78 ± .32)	352	Girls	41.92 (6.57)	34.34 (5.51)	
Kim et al[46]	*3-10 (6.8 ± 1.9)	139		36.82 (9.08)	31.33 (9.63)	
	Age	**n**	**Group**	**RAW**		
				LOCO	**OC**	**Total**
Lin & Yang[45]	6-7	92		23.49 (5.41)	27.41 (6.52)	50.90 (9.02)
	7-8	197		25.34 (5.12)	28.25 (6.15)	53.59 (8.50)
	8-9	196		26.74 (5.32)	30.77 (5.82)	57.52 (8.85)
	6-9y	244	Boys	25.36 (5.57)	31.48 (5.67)	56.84 (8.70)
	6-9y	241	Girls	25.76 (5.19)	26.71 (5.88)	52.47 (8.95)
Liong et al[44]	5-8	66	Girls	32.2 (5.3)	26.7 (6.5)	58.9 (10.5)
	5-8	69	Boys	30.2 (5.7)	32.3 (8.1)	62.4 (11.3)
	5-8 (6.5 ± 1.1)	135		31.2 (5.6)	29.6 (7.8)	60.7 (11.0)
Mukherjee et al[55]	6-0 to 6-5 (6.34 ± .07)	13	Girls	34.00 (4.20)	19.31 (4.33)	
	6-0 to 6-5 (6.32 ± .07)	12	Boys	35.33 (5.43)	25.08 (6.35)	
	6-6 to 6-11 (6.70 ± .14)	38	Boys	35.18 (5.84)	26.87 (6.01)	
	6-6 to 6-11 (6.71 ± .15)	32	Girls	34.97 (4.98)	24.16 (4.97)	
	7-0 to 7-5 (7.04 ± .06)	15	Girls	35.07 (6.04)	22.07 (4.80)	
	7-0 to 7-5 (7.04 ± .05)	10	Boys	36.10 (4.53)	24.80 (5.22)	
	8-0 to 8-11 (8.79 ± .09)	14	Girls	37.86 (4.83)	29.43 (4.57)	
	8-0 to 8-11(8.79 ± .10)	21	Boys	37.14 (5.31)	33.81 (4.90)	
	9-0 to 9-11 (9.30 ± .21)	51	Boys	37.86 (4.88)	33.61 (3.81)	
	9-0 to 9-11 (9.29 ± .21)	38	Girls	38.68 (4.59)	30.16 (5.11)	
Palmer et al[38]	5-10 (7.7)	44			28.9 (8.0)	
Pang & Fong[8]	6-0 to 6-5	15	Boys	43.8 (2.5)	38.6 (4.7)	
	6-0 to 6-5	9	Girls	44.1 (3.5)	35.7 (6.1)	
	6-6 to 6-11	12	Boys	43.4 (2.5)	41.3 (4.3)	
	6-6 to 6-11	10	Girls	43.9 (1.8)	37.8 (6.3)	
	7-0 to 7-5	15	Boys	44.6 (2.5)	43.2 (4.0)	
	7-0 to 7-5	21	Girls	43.6 (1.8)	38.9 (3.6)	
	7-6 to 7-11	13	Boys	44.7 (2.7)	44.5 (2.7)	
	7-6 to 7-11	8	Girls	43.5 (2.0)	41.0 (4.9)	
	8-0 to 8-11	28	Boys	44.9 (2.5)	44.6 (2.1)	
	8-0 to 8-11	28	Girls	45.0 (2.6)	42.5 (3.0)	
	9-0 to 9-11	8	Boys	45.5 (2.6)	44.0 (3.3)	
Robinson et al[59]	*2-7.5 (5.95 ± .80)	21		23.9 (6.9)	23.6 (7.1)	
	7.6-11.9 (8.96 ± .86)	24		30.7 (7.0)	29.6 (7.0)	
Rudd et al[57]	6-8	24	Boys	32.9 (5.3)	34.2 (5.9)	
	6-8	21	Girls	35.9 (4.7)	30.3 (4.7)	
	8-10	31	Boys	35.8 (3.8)	37.3 (4.6)	
	8-10	26	Girls	34.1 (4.2)	35.0 (3.9)	
	6-12	86	Boys	35.2 (5.0)	37.9 (5.6)	
	6-12	72	Girls	35.1 (4.4)	33.7 (4.9)	
	10-12	31	Boys	36.4 (5.3)	41.3 (4.3)	
	10-12	25	Girls	35.4 (4.3)	35.2 (4.7)	
Rudd et al[58]	Grade 1-4 (8.1 ± 1.1)	69	INT: Boys	28.3 (6.3)	30.0 (8.5)	
		66	INT: Girls	31.0 (6.1)	27.0 (7.0)	
		102	CON: Boys	28.0 (7.2)	32.0 (7.8)	
		96	CON: Girls	30.4 (5.9)	26.6 (7.4)	
Slykerman et al[56]	5-8 (6.5 ± 1.0)	109	Total	31.2 (5.6)	29.5 (8.1)	
	5-8 (6.5 ± 1.0)	59	Boys	30.4 (5.4)	32.1 (8.3)	

	5-8 (6.5 ± 1.0)	50	Girls	32.0 (5.8)	26.4 (6.7)	
Spessato et al[52]	4	48				35.50 (12.37)
	Age	**n**	**Group**	**RAW**		
				LOCO	**OC**	**Total**
Spessato et al[52]	5	58				43.81 (6.73)
	6	40				50.00 (9.44)
	7	32				59.62 (9.02)
	4-7 (5.36 ± 1.0)	178				45.80 (12.56)
Valentini[64]	4	62	Girls	23.47 (6.88)	17.24 (4.88)	
	4	61	Boys	23.61 (6.53)	21.90 (5.64)	
	5	112	Girls	26.20 (7.16)	17.78 (7.16)	
	5	108	Boys	28.10 (6.83)	24.94 (8.17)	
	6	186	Girls	28.07 (6.57)	20.76 (7.49)	
	6	173	Boys	29.09 (6.83)	27.58 (7.73)	
	7	190	Girls	29.51 (7.45)	24.11 (7.18)	
	7	222	Boys	31.13 (7.76)	31.97 (7.35)	
	8	292	Girls	29.23 (6.69)	26.75 (5.90)	
	8	285	Boys	31.32 (6.69)	34.42 (6.28)	
	9	271	Girls	30.31 (6.62)	28.44 (5.90)	
	9	266	Boys	30.88 (6.85)	35.25 (6.07)	
	10	167	Girls	31.16 (6.35)	29.67 (6.10)	
	10	185	Boys	31.99 (6.74)	36.82 (6.24)	
	*3-10	1322	Girls	28.70 (7.25)	24.62 (7.68)	
	*3-10	1352	Boys	29.91 (7.54)	31.60 (8.50)	
	*3-10 (7.56 ± 1.91)	2674		29.48 (6.13)	27.00 (8.02)	56.49 (12.42)
Wong & Cheung[66]	4	134	Boys	28.90 (9.43)	17.54 (6.27)	
	4	111	Girls	27.63 (8.78)	14.72 (5.07)	
	5	152	Boys	33.59 (6.48)	22.97 (7.61)	
	5	118	Girls	34.05 (6.09)	17.99 (5.45)	
	6	88	Boys	36.02 (5.05)	27.44 (6.71)	
	6	79	Girls	36.80 (6.32)	22.63 (6.23)	
	7	58	Boys	41.05 (4.35)	30.45 (5.69)	
	7	69	Girls	41.10 (4.06)	27.22 (5.64)	
	8	51	Boys	42.00 (2.95)	36.29 (5.36)	
	8	38	Girls	42.34 (3.06)	28.39 (6.66)	
	9	68	Boys	43.43 (3.18)	35.54 (6.65)	
	9	40	Girls	42.63 (3.69)	30.10 (5.23)	
	10	74	Boys	43.78 (2.48)	34.51 (8.75)	
	10	33	Girls	42.97 (3.31)	29.03 (5.22)	
Zuvela et al[63]	8.1 ± .3	95				59.45 (15.25)

*includes children outside 4-13y age range
Games: Games intervention group, Sports: Sports intervention group, INT: Intervention group, CON: Control group
LOCO: Locomotor, OC: Object-control, TOTAL: Total FMS

Table 4.6: Summary of the results of studies that reported raw skill scores

	Age	n	Group	Run	Gallop	Hop	Leap	Jump	Slide	Strike	Dribble	Catch	Kick	Throw	Roll
Antunes et al[42]	6 (6.72 ± .2)	27	Boys	5.9 (1.7)		6.4 (1.9)	2.5 (1.2)				5.0 (2.3)		5.0 (1.3)		
	6 (6.64 ± .2)	23	Girls		5.1 (3.0)										
	7 (7.58 ± .2)	28	Girls		6.4 (2.4)										
	7 (7.62 ± .2)	29	Boys	7.2 (1.5)		7.0 (1.6)	2.0 (1.3)				6.4 (2.3)		4.5 (2.0)		
	8 (8.59 ± .3)	27	Boys	7.5 (.9)		7.1 (1.5)	2.6 (1.0)				7.3 (1.3)		5.1 (1.0)		
	8 (8.68 ± .3)	24	Girls		7.5 (1.1)										
Bardid et al[19]	4	159	Girls	5.3 (1.8)	5.4 (2.3)	6.2 (2.7)	3.6 (1.6)	4.5 (2.0)	4.7 (2.7)	5.1 (2.2)	1.2 (1.7)	2.1 (1.5)	3.5 (1.6)	2.5 (1.9)	3.8 (1.7)
	4	215	Boys	5.3 (1.9)	4.9 (2.3)	4.9 (3.0)	3.7 (1.7)	4.5 (2.1)	4.7 (2.7)	5.5 (2.2)	1.6 (2.0)	2.7 (1.5)	4.8 (1.9)	3.5 (2.2)	4.3 (1.8)
	4	374		5.3 (1.9)	5.1 (2.3)	5.5 (3.0)	3.7 (1.7)	4.5 (2.0)	4.7 (2.7)	5.3 (2.2)	1.4 (1.9)	2.4 (1.5)	4.2 (1.9)	3.1 (2.1)	4.1 (1.8)
	5	149	Girls	5.9 (1.9)	6.0 (1.7)	7.3 (1.8)	4.0 (1.6)	5.4 (1.9)	5.8 (2.5)	6.1 (2.3)	1.8 (2.0)	3.2 (1.5)	4.2 (1.6)	3.4 (2.1)	4.6 (1.7)
	5	181	Boys	6.0 (1.8)	5.6 (2.0)	6.7 (2.3)	4.2 (1.6)	5.4 (2.0)	5.7 (2.5)	6.7 (2.3)	2.9 (2.6)	3.4 (1.6)	5.5 (1.7)	4.4 (2.2)	4.6 (1.8)
	5	330		5.9 (1.8)	5.8 (1.9)	7.0 (2.1)	4.1 (1.6)	5.4 (1.9)	5.7 (2.5)	6.4 (2.3)	2.4 (2.4)	3.3 (1.6)	4.9 (1.8)	3.9 (2.2)	4.6 (1.7)
	6	164	Girls	6.2 (1.9)	6.2 (1.8)	8.2 (1.6)	4.3 (1.4)	5.6 (1.8)	6.6 (2.1)	6.4 (2.2)	3.2 (2.6)	3.7 (1.7)	4.8 (1.8)	3.6 (1.9)	4.9 (1.7)
	6	159	Boys	6.4 (1.8)	5.8 (2.0)	8.0 (1.6)	4.3 (1.4)	5.4 (1.9)	6.5 (2.0)	6.9 (2.3)	5.1 (2.6)	4.3 (1.5)	6.2 (1.6)	5.3 (1.9)	5.4 (1.5)
	6	323		6.3 (1.9)	6.0 (1.9)	8.1 (1.6)	4.3 (1.4)	5.5 (1.8)	6.6 (2.0)	6.6 (2.3)	4.1 (2.7)	4.0 (1.6)	5.5 (1.9)	4.4 (2.1)	5.1 (1.6)
	7	107	Girls	6.5 (1.5)	6.2 (1.7)	8.4 (1.5)	4.6 (1.5)	5.8 (1.7)	7.0 (1.8)	6.4 (2.1)	4.6 (2.4)	4.3 (1.6)	4.6 (1.7)	4.7 (2.1)	5.0 (1.6)
	7	103	Boys	6.5 (1.6)	6.4 (1.5)	8.2 (1.6)	4.3 (1.4)	5.8 (1.9)	7.1 (1.5)	8.1 (2.0)	6.0 (2.2)	4.6 (1.4)	6.2 (1.8)	5.8 (1.9)	5.7 (1.6)
	7	210		6.5 (1.5)	6.3 (1.6)	8.3 (1.5)	4.4 (1.4)	5.8 (1.8)	7.0 (1.6)	7.2 (2.2)	5.3 (2.4)	4.4 (1.5)	5.4 (1.9)	5.3 (2.1)	5.4 (1.6)
	8	81	Girls	6.1 (1.6)	6.3 (1.5)	8.2 (1.5)	4.8 (1.2)	6.1 (1.9)	7.0 (1.7)	6.8 (2.2)	5.6 (2.2)	4.8 (1.3)	4.7 (1.6)	4.8 (2.1)	5.7 (1.6)
	8	62	Boys	6.8 (1.4)	6.4 (1.7)	8.5 (1.5)	4.5 (1.6)	6.2 (1.8)	7.2 (1.7)	7.6 (2.2)	6.6 (1.7)	5.0 (1.2)	6.6 (1.4)	6.3 (1.7)	6.0 (1.6)
	8	143		6.4 (1.6)	6.3 (1.5)	8.3 (1.5)	4.7 (1.4)	6.2 (1.8)	7.1 (1.7)	7.1 (2.3)	6.0 (2.0)	4.9 (1.3)	5.5 (1.8)	5.5 (2.1)	5.8 (1.6)
Butterfield et al[61]	6	7	Boys							7.14 (3.44)		5.00 (.82)	6.17 (1.33)	3.14 (2.67)	
	6	10	Girls							7.40 (2.12)		4.50 (1.78)	5.40 (1.90)	2.90 (3.14)	
	7	9	Boys							8.44 (2.19)		5.33 (.71)	6.22 (1.30)	6.00 (2.60)	
	7	12	Girls							7.58 (1.88)		4.92 (.90)	5.92 (1.44)	3.08 (2.84)	

	Age	n	Group	Run	Gallop	Hop	Leap	Jump	Slide	Strike	Dribble	Catch	Kick	Throw	Roll
Butterfield et al[61]	8	8	Boys							9.25 (.89)		5.63 (.52)	7.38 (.92)	6.00 (3.70)	
	8	5	Girls							7.80 (1.92)		5.00 (.71)	7.20 (1.10)	6.40 (.89)	
	9	9	Boys							9.56 (.88)		5.67 (.50)	7.56 (.73)	8.00 (.00)	
	9	8	Girls							6.50 (2.33)		5.50 (.76)	6.63 (1.41)	3.25 (2.60)	
	10	14	Boys							9.21 (.70)		6.00 (.00)	7.50 (1.16)	7.43 (1.22)	
	10	11	Girls							9.55 (.82)		5.82 (.40)	7.73 (.65)	7.09 (2.43)	
	11	17	Boys							9.88 (.49)		6.00 (.00)	7.88 (.49)	7.53 (.87)	
	11	11	Girls							9.27 (1.10)		5.73 (.65)	7.27 (.90)	6.73 (1.01)	
	12	10	Boys							9.80 (.42)		5.90 (.32)	7.50 (.85)	7.30 (1.34)	
	12	7	Girls							9.14 (1.21)		6.00 (.00)	7.57 (.79)	6.57 (1.62)	
	13	16	Boys							9.00 (1.21)		5.75 (.58)	7.75 (.58)	7.56 (.81)	
	13	5	Girls							9.60 (.55)		6.00 (.00)	7.80 (.45)	6.80 (1.79)	
	6-13 (10.0 ± 2.4)	96	Boys							9.16 (1.56)		5.72 (.56)	7.38 (1.03)	6.77 (2.29)	
	6-13 (9.1 ± 2.5)	75	Girls							8.17 (2.05)		5.35 (1.01)	6.73 (1.55)	5.12 (2.92)	
	6-13 (9.6 ± 2.5)	186								8.78 (2.01)		5.56 (.81)	7.53 (5.80)	6.05 (2.71)	
Capio et al[54]**	8-12 (8.6 ± .68)	20	ER: Low											6.30 (1.59)	

	Age	n	Group	Run	Gallop	Hop	Leap	Jump	Slide	Strike	Dribble	Catch	Kick	Throw	Roll
Capio et al[54]**	8-12 (8.67 ± .59)	34	ES: Low											6.53 (1.64)	
	8-12 (9.27 ± .91)	55	ES: Mid											7.38 (.91)	
	8-12 (9.34 ± .76)	53	ER: Mid											7.57 (1.06)	
	8-12 (9.53 ± .96)	28	ES: High											7.14 (1.51)	
	8-12 (9.81 ± .98)	26	ER: High											7.27 (.96)	
Du Plessis et al[51]	6.84 ± .39)	806	Grade 1							6.78 (1.84)	4.17 (2.42)	4.70 (1.12)	6.07 (1.42)	2.88 (2.34)	4.36 (1.87)
Freitas et al[35]	10 (10.6 ± .3)	69	Boys	7.3 (1.2)	7.4 (1.3)	8.0 (1.7)	3.1 (1.7)	5.6 (1.6)	7.9 (.5)	7.7 (1.9)	7.4 (1.1)	5.5 (.9)	6.2 (1.8)	6.2 (1.3)	6.9 (1.4)
	10 (10.6 ± .3)	78	Girls	7.4 (1.2)	7.6 (1.0)	8.4 (1.5)	2.8 (1.7)	5.9 (1.7)	7.9 (.5)	6.2 (2.4)	7.1 (1.3)	5.6 (.8)	4.9 (2.1)	4.9 (1.9)	6.1 (1.8)
	7 (7.5 ± .3)	48	Boys	7.0 (1.6)	6.0 (2.3)	6.7 (1.4)	2.2 (1.3)	5.4 (2.3)	7.5 (1.2)	6.1 (1.7)	6.0 (2.2)	4.3 (1.4)	4.5 (1.6)	4.9 (2.1)	6.0 (1.5)
	7 (7.5 ± .3)	45	Girls	7.0 (1.1)	6.4 (2.4)	6.9 (2.0)	2.4 (1.3)	5.4 (1.7)	7.9 (.7)	5.4 (2.2)	5.6 (2.2)	4.1 (1.4)	3.8 (1.6)	4.1 (2.0)	5.6 (1.8)
	8 (8.5 ± .3)	51	Boys	7.3 (1.1)	7.0 (1.8)	7.1 (1.6)	2.4 (1.0)	5.7 (1.8)	8.0 (.1)	7.1 (1.6)	7.2 (1.4)	4.6 (1.3)	5.1 (1.1)	5.7 (1.5)	6.3 (1.3)
	8 (8.5 ± .3)	41	Girls	7.0 (1.2)	7.2 (1.6)	7.3 (1.6)	2.9 (1.4)	5.4 (1.9)	8.0 (.2)	5.3 (1.6)	6.1 (2.1)	4.3 (1.2)	3.9 (1.3)	4.0 (2.4)	5.4 (1.6)
	9 (9.4 ± .3)	52	Girls	6.9 (1.4)	7.4 (1.6)	7.4 (1.5)	2.7 (1.2)	5.9 (1.6)	7.9 (.6)	5.9 (1.8)	7.0 (1.4)	4.9 (1.1)	4.4 (1.0)	4.2 (1.8)	6.0 (1.7)
	9 (9.5 ± .3)	45	Boys	7.3 (1.3)	7.6 (1.4)	7.7 (2.0)	2.6 (1.4)	6.2 (1.5)	7.8 (.8)	7.2 (2.7)	7.4 (1.2)	5.2 (.9)	5.2 (1.6)	5.9 (1.5)	6.0 (1.9)
Kim et al[46]*	3-10 (6.8 ± 1.9)	139		6.53 (1.77)	5.50 (2.00)	7.60 (2.91)	4.83 (1.44)	5.50 (2.38)	6.86 (1.71)	6.88 (2.64)	3.12 (2.76)	5.32 (1.55)	5.70 (1.92)	5.20 (2.52)	5.12 (2.41)
Lin & Yang[45]	6-7	92		6.57 (1.42)	2.86 (1.92)	4.89 (2.53)	4.65 (1.09)	3.01 (1.81)	1.51 (2.15)	5.80 (2.14)	4.08 (1.95)	3.23 (1.44)	6.25 (1.63)	4.24 (2.35)	3.82 (2.03)
	7-8	197		6.95 (1.19)	3.33 (1.90)	4.34 (2.31)	4.74 (1.10)	4.14 (2.10)	1.85 (2.42)	5.47 (2.52)	4.17 (2.04)	3.47 (1.32)	6.19 (1.71)	5.01 (2.40)	3.93 (2.08)
	8-9	196		7.51 (.81)	3.05 (1.65)	4.43 (2.10)	4.95 (1.08)	4.07 (2.09)	2.73 (2.81)	5.74 (2.52)	4.80 (2.14)	3.96 (1.29)	6.53 (1.78)	5.64 (2.16)	4.10 (2.18)
	6-9	244	Boys	7.06 (1.17)	3.05 (1.79)	4.36 (2.18)	4.80 (1.09)	3.83 (2.06)	2.25 (2.64)	6.48 (2.40)	4.62 (2.13)	3.73 (1.33)	6.47 (1.82)	5.80 (2.31)	4.38 (2.11)
	6-9	241	Girls	7.15 (1.16)	3.20 (1.84)	4.60 (2.37)	4.81 (1.11)	3.96 (2.11)	2.03 (2.52)	4.80 (2.21)	4.19 (2.02)	3.51 (1.38)	6.21 (1.63)	4.44 (2.19)	3.57 (2.03)

	Age	n	Group	Run	Gallop	Hop	Leap	Jump	Slide	Strike	Dribble	Catch	Kick	Throw	Roll
Miller et al[39]	11.12 ± 1.28	97	INT									3.56 (1.10)	4.98 (1.99)	2.10 (1.83)	
	11.20 ± .61	71	CON									3.91 (.90)	5.38 (1.85)	2.33 (2.15)	
Palmer et al[38]	5-10 (7.7)	44								6.1 (2.0)	5.4 (2.2)	5.1 (1.2)	4.1 (1.7)	4.0 (2.7)	4.2 (2.4)
Pienaar et al[60]	9-10 (9.9 ± .46)	433	Boys							8.96 (1.42)	7.09 (1.42)	5.76 (.67)	7.63 (.76)	6.55 (1.53)	6.41 (1.44)
	9-10 (9.9 ± .46)	393	Girls							8.37 (1.58)	6.70 (1.72)	5.78 (.55)	7.12 (1.16)	6.14 (1.64)	6.03 (1.45)
	9-10 (9.9 ± .63)	826	Total							8.68 (1.53)	6.91 (1.58)	5.77 (.62)	7.39 (1.00)	6.36 (1.59)	6.23 (1.46)
Valentini[64]*	3-10 (7.56 ±1.91)	2674		6.24 (1.81)	5.20 (1.84)	5.22 (1.86)	4.05 (1.41)	3.26 (1.83)	5.46 (2.54)	5.89 (2.28)	3.99 (2.87)	4.23 (1.68)	4.13 (1.99)	3.99 (2.36)	4.18 (2.20)

*includes children outside 4-13y age range

**ER: Error-reduced training group, ES: Error-strewn training group, Low: Low ability group, Mid: Mid-ability group, High: High ability group

Table 4.7: Summary of the results of studies that reported standard scores, gross motor quotient, percentile and/or age equivalent scores

	Age	n	Group	SS			GMQ	Mean Percentile		Percentile Rank	Age Eq.	
				LOCO	OC	Total		LOCO	OC		LOCO	OC
Bakhtiari et al[65]	9 (8.9 ± .48)	20	CON	3.2 (1.32)	6.9 (2.35)					70.4 (8.04)		
	9 (8.9 ± .49)	20	INT	3.3 (1.98)	5.05 (2.28)					65.2 (10.63)		
Bardid et al[19]	4	159	Girls	10.6 (2.4)	8.2 (1.8)		96.3 (10.3)					
	4	215	Boys	10.0 (2.7)	8.7 (2.0)		96.1 (11.6)					
	4	374		10.2 (2.6)	8.5 (1.9)		96.2 (11.1)					
	5	149	Girls	10.3 (2.4)	8.2 (2.2)		95.5 (10.8)					
	5	181	Boys	10.0 (2.3)	8.4 (2.0)		95.4 (10.6)					
	5	330		10.2 (2.4)	8.3 (2.1)		95.5 (10.7)					
	6	164	Girls	9.5 (2.5)	7.8 (2.3)		91.9 (11.8)					
	6	159	Boys	9.4 (2.4)	8.3 (2.2)		93.0 (10.9)					
	6	323		9.5 (2.4)	8.0 (2.3)		92.5 (11.4)					
	7	107	Girls	9.0 (2.3)	7.4 (2.5)		89.1 (11.6)					
	7	103	Boys	8.7 (2.3)	7.7 (2.3)		89.0 (10.2)					
	7	210		8.8 (2.3)	7.5 (2.4)		89.1 (10.9)					
	8	81	Girls	7.8 (2.2)	7.0 (2.4)		84.3 (9.8)					
	8	62	Boys	8.5 (2.7)	7.1 (2.1)		86.8 (11.7)					
	8	143		8.1 (2.5)	7.1 (2.3)		85.4 (10.7)					
	3-8*	773	Girls	9.6 (2.5)	8.0 (2.2)		92.9 (11.5)					
	3-8*	841	Boys	9.5 (2.5)	8.4 (2.1)		93.6 (11.3)					
	3-8*	1614		9.6 (2.5)	8.2 (2.2)		93.2 (11.4)					
Burrows et al[53]	7.64 ± 1.06	25	Games				83.20 (12.09)					
	8.05 ± 1.08	15	Sports				89.20 (10.26)					
Cepicka[62]	7.1 ± .3	152	Boys					22.16 (17.00)	20.98 (17.22)			
	7.0 ± .3	163	Girls					35.29 (21.09)	23.60 (20.08)			
De Meester et al[40]	9.50 ± 1.24	361								18.97 (21.78)		
		180	Boys							18.24 (20.66)		

	Age	n	Group	SS			GMQ	Mean Percentile		Percentile Rank	Age Eq.	
				LOCO	OC	Total		LOCO	OC		LOCO	OC
		181	Girls							19.69 (22.89)		
Grant-Beuttler et al[49]	4 (4.5 ± .4)	9		14.4 (2.9)	13.3 (1.9)		123.3 (9.9)					
	4	4	Boys	16.8 (3.3)	13.8 (1.0)		131.5 (7.1)					
	4	5	Girls	12.8 (1.3)	12.8 (2.6)		116.8 (6.2)					
	5 (5.7 ± .2)	9		12.8 (2.5)	11.3 (2.2)		113.0 (10.4)					
	5	5	Boys	13.2 (3.4)	12.2 (1.3)		117.4 (9.8)					
	5	4	Girls	12.3 (1.3)	10.3 (2.9)		107.5 (9.3)					
	6 (6.4 ± .2)	9		11.9 (3.5)	10.8 (2.8)		108.0 (17.0)					
	6	4	Boys	12.8 (4.9)	11.5 (3.7)		112.75 (23.7)					
	6	5	Girls	11.2 (2.2)	10.2 (2.2)		104.2 (10.9)					
	7 (7.5 ± .2)	9		10.8 (2.1)	10.8 (2.9)		104.7 (14.8)					
	7	5	Boys	10.4 (2.6)	9.6 (3.4)		100.0 (17.0)					
	7	4	Girls	11.3 (1.5)	12.3 (1.3)		110.5 (7.9)					
	8 (8.2 ± .2)	9		11.2 (1.7)	10.8 (2.7)		106.0 (11.8)					
	8	5	Boys	11.0 (1.9)	9.0 (2.0)		100.0 (11.4)					
	8	4	Girls	11.5 (1.7)	13.9 (1.6)		113.5 (7.9)					
	9 (9.7 ± .3)	9		10.2 (2.5)	11.3 (2.1)		104.7 (10.0)					
	9	4	Boys	9.25 (3.5)	11.5 (2.4)		102.25 (14.8)					
	9	5	Girls	11.0 (1.4)	11.2 (2.2)		106.6 (4.9)					
Johnstone et al[48]	7.0 ± 1.1	102	INT	7.5 (2.1)	6.9 (2.4)		83.2 (11.6)	24.6 (18.8)	21.5 (20.0)	18.9 (17.8)		
	7.4 ± .9	21	CON	7.5 (1.6)	8.0 (2.7)		86.6 (11.2)	23.0 (13.7)	30.0 (25.9)	23.4 (19.8)		
Khodaverdi et al[47]	8-9 (8.78 ± .32)	352	Girls				76.26 (9.28)					
Logan et al[43]		32	Boys	5.7 (2.1)	8.7 (1.9)		82.9 (9.4)					
		33	Girls	5.9 (1.8)	8.8 (2.0)		84.0 (8.8)					
	6.7 ± .34	22	Grade 1	6.2 (1.9)	9.2 (1.7)		86.2 (8.6)					
	7.8 ± .46	23	Grade 2	5.1 (2.3)	8 (2.2)		79.5 (10.1)					

	Age	n	Group	SS			GMQ	Mean Percentile		Percentile Rank	Age Eq.	
				LOCO	OC	Total		LOCO	OC		LOCO	OC
	5-8	65	K-Grade 2	5.8 (2.0)	8.7 (2.0)		83.5 (9.1)					
Mukherjee et al[55]	6-0 to 6-5 (6.32 ± .07)	12	Boys	9.08 (2.54)	6.17 (2.08)	15.25 (3.41)	85.75 (10.24)	37.50 (23.70)	14.50 (14.80)	20.92 (20.69)	6-0	4-3
	6-6 to 6-11 (6.70 ± .14)	38	Boys	8.45 (2.37)	5.79 (1.97)	14.24 (3.47)	82.71 (10.40)	32.89 (22.00)	12.03 (12.03)	16.84 (17.03)	6-0	4-6
	7-0 to 7-5 (7.04 ± .05)	10	Boys	7.90 (1.66)	4.00 (1.83)	11.90 (2.23)	75.70 (6.70)	27.10 (15.16)	4.40 (5.17)	6.60 (4.86)	6-0	4-3
	8-0 to 8-11 (8.79 ± .10)	21	Boys	7.19 (1.99)	5.14 (1.96)	12.33 (3.12)	77.00 (9.36)	21.67 (15.54)	8.76 (10.56)	9.48 (9.44)	6-6	5-9
	9-0 to 9-11 (9.30 ± .21)	51	Boys	6.90 (2.39)	6.16 (1.25)	13.06 (2.72)	79.18 (8.15)	20.69 (19.47)	11.84 (7.64)	10.94 (10.39)	6-9	5-9
	6-0 to 6-5 (6.34 ± .07)	13	Girls	8.31 (1.49)	5.08 (1.50)	13.38 (2.53)	80.15 (7.60)	30.69 (15.92)	7.00 (6.73)	11.69 (9.01)	5-6	3-9
	6-6 to 6-11 (6.71 ± .15)	32	Girls	8.50 (2.11)	6.59 (1.97)	15.09 (3.24)	85.28 (9.71)	32.50 (20.82)	17.16 (15.47)	20.09 (17.34)	6-0	4-9
	7-0 to 7-5 (7.04 ± .06)	15	Girls	7.80 (2.24)	4.87 (2.00)	12.67 (2.41)	78.00 (7.23)	27.73 (20.94)	7.87 (9.92)	9.07 (7.82)	6-0	4-6
	8-0 to 8-11 (8.79 ± .09)	14	Girls	7.64 (2.37)	5.79 (1.89)	13.43 (3.23)	80.29 (9.68)	26.00 (23.69)	11.21 (7.20)	13.29 (14.26)	6-9	5-9
	9-0 to 9-11 (9.29 ± .21)	38	Girls	7.34 (2.18)	5.58 (2.13)	12.92 (3.44)	78.76 (10.31)	23.76 (17.75)	11.16 (13.41)	11.76 (10.39)	7-0	6-3
Pang & Fong[8]	6-0 to 6-5	15	Boys	13.7 (2.1)	10.5 (1.7)	24.3 (2.7)	112.6 (8.5)	84.6 (15.7)	57.7 (20.1)	77.0 (16.4)	10-0	6-9
	6-6 to 6-11	12	Boys	12.4 (2.0)	10.8 (1.8)	23.3 (2.9)	109.8 (8.6)	74.8 (17.1)	59.3 (21.0)	71.5 (17.1)	8-6	7-3
	7-0 to 7-5	15	Boys	12.5 (1.9)	11.0 (2.0)	23.5 (3.4)	110.4 (10.1)	75.9 (19.0)	61.7 (23.2)	72.6 (21.2)	>10-9	8-6
	7-6 to 7-11	13	Boys	12.0 (1.7)	11.2 (1.7)	23.2 (3.1)	109.7 (9.4)	72.5 (19.4)	64.0 (19.1)	71.5 (20.3)	>10-9	10-6
	8-0 to 8-11	28	Boys	11.7 (1.8)	10.5 (1.3)	22.2 (2.1)	106.5 (6.2)	69.4 (21.5)	56.4 (15.3)	65.8 (14.7)	>10-9	10-6
	9-0 to 9-11	8	Boys	11.3 (1.9)	9.6 (2.4)	20.9 (3.1)	102.6 (9.3)	64.4 (22.6)	46.6 (26.8)	56.8 (22.1)	>10-9	9-3
	6-0 to 6-5	9	Girls	14.0 (2.4)	11.7 (2.6)	25.7 (4.4)	117.3 (13.2)	85.2 (19.9)	66.6 (27.7)	80.9 (22.7)	10-0	7-6
	6-6 to 6-11	10	Girls	12.9 (1.8)	12.0 (2.6)	24.9 (3.9)	114.7 (11.6)	79.8 (16.1)	69.8 (26.5)	78.8 (22.5)	10-0	8-0
	7-0 to 7-5	21	Girls	11.7 (1.5)	11.5 (1.6)	23.2 (2.5)	109.6 (7.6)	69.6 (16.3)	67.3 (15.4)	71.8 (15.3)	10-0	8-3
	7-6 to 7-11	8	Girls	11.4 (1.5)	11.6 (2.2)	23.0 (2.9)	109.0 (8.6)	65.9 (17.2)	67.6 (24.6)	70.3 (18.6)	10-0	9-6
	8-0 to 8-11	28	Girls	11.6 (1.8)	12.0 (1.8)	23.6 (3.1)	110.9 (9.4)	68.5 (21.4)	72.6 (20.0)	73.8 (20.4)	>10-9	>10-9
Pienaar et al[60]	9.9 ± .63	826			9.23 (2.32)				41.65 (24.61)			8.89 (1.61)
	9.9 ± .46	433	Boys		8.79 (2.21)				37.53 (23.09)			8.72 (1.69)
	9.9 ± .46	393	Girls		9.73 (2.35)				46.33 (25.45)			9.08 (1.50)
Spessato et al[27]	3-4 (4.0 ± .5)	109	Boys								3.57 (1.00)	3.25 (.91)

	Age	n	Group	SS			GMQ	Mean Percentile		Percentile Rank	Age Eq.	
				LOCO	OC	Total		LOCO	OC		LOCO	OC
	5-6 (6.1 ± .6)	175	Boys								4.68 (1.14)	4.54 (1.55)
	7-8 (7.9 ± .6)	177	Boys								5.03 (1.43)	5.56 (1.51)
	9-10 (9.9 ± .5)	180	Boys								5.59 (1.11)	6.29 (1.67)
	3-4 (4.0 ± .5)	103	Girls								3.49 (.96)	3.10 (.76)
	5-6 (6.1± .5)	173	Girls								4.50 (1.06)	3.88 (1.32)
	7-8 (8.1 ± .6)	149	Girls								4.72 (1.22)	4.62 (1.16)
	9-10 (9.8 ± .5)	182	Girls								5.25 (1.08)	5.63 (1.25)

*includes children outside 4-13y age range
LOCO: Locomotor, OC: Object-control
SS: Standard Score
GMQ: Gross Motor Quotient
Age Eq.: Age Equivalent
CON: Control group, INT: Intervention group
Games: Games intervention group, Sports: Sports intervention group
K: Kindergarten

Raw Subset Scores

Table 4.8 presents weighted mean and standard deviation scores based on all studies that have included raw scores (subset, total, skill), standardised scores (subset, GMQ) or mean percentiles (subset and percentile rank) across the individual age groups and age ranges. The weighted mean raw LOCO and OC subset scores increased with age (Figure 4.2), with the exception of a lower score among 9-year-olds compared with the 8-year-old cohort. The weighted mean raw LOCO subset score ranged from 27.7 (58% of maximum) for 4-year-olds to 35.7 (74% of maximum possible score) for 10-year-olds. Raw OC subset score ranged from 18.9 (39% of maximum possible score) for 4-year-olds to 34.2 (71% of maximum score possible) for 10-year-olds. The weighted mean raw subset scores also increased across the age ranges, with the young age group (4-8 years) achieving scores of 32.2 (67% of maximum possible) and 26.2 (55%), while the older group (8-13 years) obtained scores of 35.0 (73%) and 33.1 (69%), respectively. Across all studies reporting raw subset scores (4-13 years), the weighted mean scores for LOCO and OC were 33.2 (69%) and 29.1 (61%), respectively. All weighted mean LOCO subset scores in each of the age categories and age ranges were higher than the respective OC subset score (Figure 4.2).

Gross Motor Quotient and Standard Scores

GMQ, LSS and OCSS, which are standardised scores based on age and sex, are a valuable measure of FMS proficiency as they allow proficiency levels to be directly compared across children. The weighted mean GMQ ranged from 77.2 (7-year-olds) to 96.8 (4-year-olds). According to TGMD-2 descriptive rating categories (ranging from *very poor* to *very superior*), the 4-year, 5-year and 6-year-old age groups, as well as the 4-8 years and 4-13 years age ranges are classified as *average* (range: 90-110). The 8-year and 9-year age groups as well as the 8-13 years age range are classified as *below average* (range: 80-89), while the 7-year-old group are categorized as *poor* (range: 70-79) for overall FMS proficiency (Table 4.8).

The weighted mean LSS ranged from 6.5 (9-year-olds) to 10.3 (4- and 5-year-olds) and the weighted mean OCSS ranged from 7.8 (7-year-olds) to 8.8 (9-year-olds). According to the TGMD-2 SS classifications, the weighted mean LSS of the 9-year-old age group are classified as *below average* (range: 6-7), with the 4- to 8-year-old individual age groups and all age ranges (4-8 years, 8-13 years, 4-13 years) categorised as *average* (range: 8-12). For weighted mean OCSS, all individuals age groups (4- to 9-year-olds) and age ranges (4-8 years, 8-13 years, 4-13 years) are categorized as *average* (range: 8-12).

Table 4.8: Weighted mean and standard deviation scores across age groups and age ranges

	Raw Score															SS			GMQ Score	Percentile		
	LOCO	OC	Total	Run	Gallop	Hop	Leap	Jump	Slide	Strike	Dribble	Catch	Kick	Throw	Roll	LOCO	OC	Total		LOCO	OC	Rank
4y	27.7	18.9	35.5	5.3	5.1	5.5	3.7	4.5	4.7	5.3	1.4	2.4	4.2	3.1	4.1	10.3	8.6		96.8			
SD	2.1	2.6	*	*	*	*	*	*	*	*	*	*	*	*	*	.9	1.0		5.8			
n	742	742	48	374	374	374	374	374	374	374	374	374	374	374	374	383	383		383			
5y	32.1	22.9	46.8	5.9	5.8	7.0	4.1	5.4	5.7	6.4	2.4	3.3	4.9	3.9	4.6	10.3	8.4		96.0			
SD	3.4	3.6	9.7	*	*	*	*	*	*	*	*	*	*	*	*	.6	.7		4.0			
n	820	820	74	330	330	330	330	330	330	330	330	330	330	330	330	339	339		339			
6y	32.9	27.0	52.1	6.3	5.3	7.3	4.3	4.9	5.5	6.7	4.2	4.4	5.9	3.4	4.5	9.6	8.0	17.8	92.7	48.7	29.4	37.0
SD	5.1	4.3	5.4	.2	1.6	1.6	.6	1.5	3.0	.3	.1	.5	.3	.8	.5	1.5	1.5	5.0	8.3	24.3	25.0	29.7
n	1132	1109	147	442	438	442	442	415	415	1238	1248	1238	1265	1238	1221	495	495	141	495	141	141	141
7y	33.9	30.0	55.0	6.8	5.2	6.5	4.0	5.1	5.1	6.3	5.0	4.0	5.5	5.0	4.9	8.6	7.8	19.9	77.2	32.4	26.4	32.7
SD	5.2	4.0	3.8	.3	1.6	2.0	1.1	.9	3.0	1.0	.8	.5	.8	.5	.9	1.7	1.7	5.5	15.5	15.6	14.9	26.2
n	1518	1490	242	529	528	529	529	500	500	521	529	521	550	521	500	447	447	82	545	520	520	205
8y	35.2	32.7	58.7	7.1	5.1	6.3	4.3	5.1	5.3	6.4	5.7	4.4	5.8	5.5	5.0	8.9	7.9	19.0	82.3	51.4	43.4	47.2
SD	6.2	4.0	3.2	.5	2.1	1.9	1.1	1.1	2.7	.9	1.0	.5	.9	.5	1.0	1.8	2.3	5.7	10.6	25.6	31.6	33.3
n	1606	1582	308	458	455	458	458	431	431	444	458	444	471	444	431	243	243	91	610	91	91	91
9y	34.1	32.5	68.2	7.1	7.5	7.5	2.7	6.0	7.9	8.6	6.9	5.7	7.2	6.3	6.2	6.5	8.8	13.7	83.0	25.5	38.8	22.5
SD	5.2	3.6	*	.3	.1	.2	.1	.2	.1	.6	.2	.2	.7	.5	.2	2.5	1.3	2.7	10.5	14.4	10.3	16.1
n	839	839	23	97	97	97	97	97	97	1766	1749	1766	1766	1766	1749	146	972	97	106	97	923	490
10y	35.7	34.2	65.5	7.4	7.5	8.2	2.9	5.8	7.9	7.3	7.2	5.6	5.8	5.8	6.5							
SD	5.4	3.9	*	.1	.1	.3	.2	.2	.0	1.3	.2	.2	1.1	1.0	.6							
n	606	606	8	147	147	147	147	147	147	172	147	172	172	172	147							
11y										9.6		4.0	5.5	2.9								
SD										.4		.9	1.0	2.0								
n										28		196	196	196								
12y										9.5		5.9	7.5	7.0								
SD										.5		.1	.0	.5								
n										17		17	17	17								
13y										9.1		5.8	7.8	7.4								
SD										.4		.2	.0	.0								
n										21		21	21	21								
4-8y	32.2	26.2	53.1	6.1	5.3	6.6	4.1	5.0	5.1	6.4	3.7	3.9	5.5	3.7	4.5	9.6	8.2	18.6	93.3	35.9	27.0	34.5
SD	4.7	5.5	6.3	.6	1.1	1.5	.6	.8	2.0	.7	1.3	.9	.7	.9	.5	1.4	1.3	5.1	7.5	18.6	17.1	26.9
n	4477	4528	646	1630	1625	1630	1630	1574	1574	2418	2436	2418	2474	2418	2380	1664	1664	223	1689	661	661	346

	Raw Score															SS			GMQ Score	Percentile		
	LOCO	OC	Total	Run	Gallop	Hop	Leap	Jump	Slide	Strike	Dribble	Catch	Kick	Throw	Roll	LOCO	OC	Total		LOCO	OC	Rank
8-13y	35.0	33.1	59.5	7.1	6.0	6.9	.2	5.4	6.2	7.8	6.6	5.2	6.5	5.9	5.9	8.0	8.6	16.2	82.4	38.1	39.2	26.0
SD	**5.5**	**3.8**	**3.4**	**.4**	**2.0**	**1.7**	**4.0**	**.9**	**2.4**	**1.3**	**.8**	**.8**	**1.1**	**1.4**	**.8**	**2.3**	**1.5**	**5.0**	**8.6**	**23.6**	**12.7**	**20.9**
n	3188	3164	339	702	699	702	702	675	675	1614	1528	1790	1817	1980	1501	389	1215	188	716	188	1014	589
4-13y	33.2	29.1	55.4	6.5	5.5	6.7	4.0	5.1	5.6	6.9	4.8	4.5	5.8	4.7	5.1	9.4	8.3	17.5	91.3	36.4	34.4	29.1
SD	**5.1**	**5.7**	**1.1**	**.7**	**1.4**	**1.5**	**.8**	**.8**	**2.1**	**1.2**	**1.8**	**1.0**	**1.1**	**1.5**	**.9**	**1.3**	**1.1**	**5.1**	**7.7**	**19.4**	**15.5**	**23.1**
n	8274	8345	985	2516	2508	2516	2516	2433	2433	4280	4192	4448	4531	4664	4109	3667	4493	411	4019	849	1675	935

*no standard deviation as only one study included in the calculation of the weighted mean
LOCO: Locomotor, OC: Object-control, SS: Standard Score, GMQ: Gross Motor Quotient
y: years

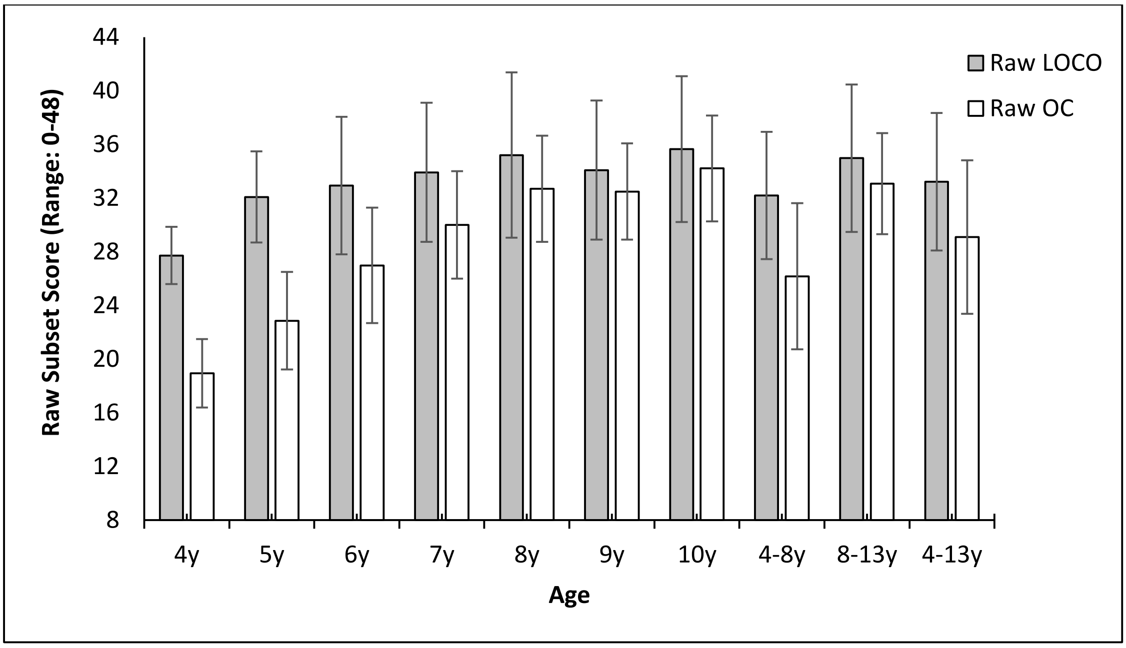

Figure 4.2: Weighted mean raw subset scores (± standard deviation) across age groups and age ranges
y: years, LOCO: Locomotor, OC: Object-control
*no studies reporting raw subset scores for 11y, 12y or 13y children

TGMD-2 Descriptive Rating Categories

Children were individually classified across the TGMD-2 descriptive ratings for LSS, OCSS and GMQ (ranging from *very poor* to *superior*) in five studies (Table 4.9). The weighted frequency across each category (Table 4.10) indicated that the greatest portion of children (within each of the age ranges: 4-8 years, 8-13 years and 4-13 years) were classified as *average* for LSS (46-67%), OCSS (58-60%) and GMQ (49-52%), with the exception of the 8-13 years age range for GMQ, in which the highest proportion of children were classified as *poor* (26.6%). For LSS, OCSS and GMQ, ≤4% of children (across the three age ranges) were classified as either *superior* or *very superior*. In contrast, on the lowest end of the continuum, greater proportions of children (across the three age ranges) were classified as either *poor* or *very poor* for LSS (range: 4-16%), OCSS (range: 8-12%) and GMQ (range: 13-36%).

Table 4.9: Summary of the results of studies that reported distribution across (i.e. proportion of children) TGMD-2 performance categories

	Age	n	Group	Loco GMQ Categories							OC GMQ Categories							GMQ Categories						
				VP	P	BA	A	AA	S	VS	VP	P	BA	A	AA	S	VS	VP	P	BA	A	AA	S	VS
Bardid et al[19]	3-8*	1614		.5	3.9	15.9	68.2	8.4	2.4	.8	2	8.1	27.9	59.7	2	.3	0	1.5	11.3	24.6	55.9	5.3	1.3	0
Mukherjee et al[55]	6-7.5	60	Boys	1.7	6.7	18.3	68.3	0	5.0	0	16.7	31.7	36.7	15.0	0	0	0	8.3	43.3	31.7	15.0	1.7	0	0
	6-7.5	60	Girls	0	5	26.7	65.0	1.7	1.7	0	13.3	36.7	28.3	21.7	0	0	0	8.3	33.3	38.3	18.3	1.7	0	0
	8-10	72	Boys	6.9	20.8	26.4	43.1	2.8	0	0	6.9	30.6	47.2	15.3	0	0	0	13.9	44.4	30.6	11.1	0	0	0
	8-10	52	Girls	5.8	13.5	26.9	51.9	1.9	0	0	15.4	19.2	53.8	11.5	0	0	0	15.4	34.6	36.5	13.5	0	0	0
Pang & Fong[8]	6-0 to 6-5	15	Boys	0	0	0	33	27	40	0	0	0	0	80	20	0	0	0	0	0	20	47	33	0
	6-6 to 6-11	12	Boys	0	0	0	58	25	17	0	0	0	0	83	17	0	0	0	0	0	58	25	17	0
	7-0 to 7-5	15	Boys	0	0	0	53	33	13	0	0	0	7	73	20	0	0	0	0	7	33	47	13	0
	7-6 to 7-11	13	Boys	0	0	0	54	46	0	0	0	0	0	69	31	0	0	0	0	8	46	31	15	0
	8-0 to 8-11	28	Boys	0	0	4	39	57	0	0	0	0	4	93	4	0	0	0	0	0	68	32		0
	9-0 to 9-11	8	Boys	0	0	0	63	38	0	0	0	0	25	63	13	0	0	0	0	0	13	63	25	0
	6-9	91	Boys	0	0	1	37	41	11	0	0	0	4	80	15	0	0	0	0	3	52	35	10	0
	6-0 to 6-5	9	Girls	0	0	0	22	22	56	0	0	0	0	56	33	11	0	0	0	0	22	33	44	0
	6-6 to 6-11	10	Girls	0	0	0	40	40	20	0	0	0	0	60	20	20	0	0	0	0	30	30	40	0
	7-0 to 7-5	21	Girls	0	0	0	76	24	0	0	0	0	0	86	9	5	0	0	0	0	67	29	5	0
	7-6 to 7-11	8	Girls	0	0	0	63	38	0	0	0	0	0	63	38	0	0	0	0	0	50	38	13	0
	8-0 to 8-11	28	Girls	0	0	0	46	54	0	0	0	0	0	57	43	0	0	0	0	4	32	46	18	0
	6-9	76	Girls	0	0	0	53	38	9	0	0	0	0	66	29	5	0	0	0	1	42	37	20	0
	6-0 to 6-5	24		0	0	0	29	25	46	0	0	0	0	71	25	4	0	0	0	0	29	42	29	0
	6-6 to 6-11	22		0	0	0	50	32	18	0	0	0	0	73	18	9	0	0	0	0	46	27	27	0
	7-0 to 7-5	36		0	0	0	67	28	6	0	0	0	3	81	14	3	0	0	0	3	53	36	8	0
	7-6 to 7-11	21			0	0	57	43	0	0	0	0	0	67	33	0	0	0	0	5	48	33	14	0
	8-0 to 8-11	56			0	0	43	55	0	0	0	0	2	75	23	0	0	0	0	2	50	39	9	0
	9-0 to 9-11	8			0	0	63	38	0	0	0	0	25	63	13	0	0	0	0	11	56	25	0	0
	6-9 (7.6 ± .9)	167			0	1	50	39	10	0	0	0	2	74	22	2	0	0	0	2	47	36	14	0
Pienaar et al[60]	9.9 ± .63	826			0	0	0	0	0	0	0.2	4.8	17.9	69.1	6.79	1.2	0	0	0	0	0	0	0	0
Spessato et al[52]	4-7 (5.36 ± 1.0)	178			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	44	28	14	12

*includes children outside 4-13y age range
VP: Very Poor, P: Poor, BA: Below Average, A: Average, AA: Above Average, S: Superior, VS: Very Superior
LOCO: Locomotor, OC: Object-control, GMQ: Gross Motor Quotient

Table 4.10: Weighted frequency of the proportion of children in each TGMD-2 performance category, across age ranges

	Loco GMQ Categories							OC GMQ Categories							GMQ Categories						
	VP	**P**	**BA**	**A**	**AA**	**S**	**VS**	**VP**	**P**	**BA**	**A**	**AA**	**S**	**VS**	**VP**	**P**	**BA**	**A**	**AA**	**S**	**VS**
4-8y	.5	3.8	15.4	67.2	9.2	3.3	.7	2.7	9.3	26.7	57.8	3.0	.5	.0	1.7	11.3	22.1	51.8	8.6	3.3	1.1
n	1837	1837	1837	1837	1837	1837	1837	1837	1837	1837	1837	1837	1837	1837	2015	2015	2015	2015	2015	2015	2015
8-13y	4.3	11.7	18.1	46.3	19.7	.0	.0	1.5	7.1	21.0	62.6	6.8	1.0	.0	9.6	26.6	22.3	23.4	14.4	3.7	.0
n	188	188	188	188	188	188	188	1014	1014	1014	1014	1014	1014	1014	188	188	188	188	188	188	188
4-13y	.8	4.5	15.7	65.3	10.2	2.9	.6	2.3	8.5	24.7	59.5	4.3	.7	.0	2.4	12.6	22.1	49.4	9.1	3.3	1.0
n	2025	2025	2025	2025	2025	2025	2025	2851	2851	2851	2851	2851	2851	2851	2203	2203	2203	2203	2203	2203	2203

VP: Very Poor, P: Poor, BA: Below Average, A: Average, AA: Above Average, S: Superior, VS: Very Superior
LOCO: Locomotor, OC: Object-control, GMQ: Gross Motor Quotient
y: years

Mastery Levels (% achieving mastery)

The proportion of children achieving mastery (i.e. mastery levels) in each of the skills assessed were reported in three studies[55,61,66] (Table 4.11). The weighted frequency of children achieving mastery in each of the 12 FMS, based on the assessment of 1357-1528 children (when sample data from all three studies were combined together) are displayed in Table 4.12.

The skill with the highest proportion of children achieving mastery was the run, across the 4- to 10-year-old age groups (ranging from 36% of 4-year-olds to 92% of 10-year-olds), with the exception of the 5-year-old age group, in which it was the 2nd most proficient skill (71%) after the strike (74%). It was also found to be the most proficient skill across the 4-8 years, 8-13 years and 4-13 years age ranges (ranging from 65%-88%). Another locomotor skill, the gallop, was also among the top 3 most proficient skills among the 6-9 year old age groups (50-78%) as well as all three age ranges (range: 43-78%). Among the least proficient skills (i.e. those with the lowest proportion achieving mastery) were the throw and the roll (object-control skills), which were among the four least proficient skills across all age categories and ranges. The hop, another object-control skill was also among the least proficient skills (among the bottom four skills for all ages and ranges except the 4-year-old age group).

Table 4.11: Summary of the results of studies that reported mastery levels

	Age	N	Group	% Mastery											
				Run	Gallop	Hop	Leap	Jump	Slide	Strike	Dribble	Catch	Kick	Throw	Roll
Butterfield et al[61]	6-13 (10.0 ± 2.4)	96	Boys							61.5		77.1	67.4	66.7	
	6-13 (9.1 ± 2.5)	75	Girls							40		60	48	32	
Mukherjee et al[55]	6-10	244		78.3	78.3	15.6	42.6	2.9	39.3	11.5	9	19.3	8.2	8.6	7.8
	6	95		77.9	72.6	16.8	40	2.1	27.4	4.2	1.1	6.3	5.3	4.2	5.3
	7	25		80	84	4	44	4	32	4	0	0	12	8	8
	8	35		74.3	77.1	17.1	37.1	8.6	48.6	14.3	20	31.4	14.3	5.7	8.6
	9	89		79.8	83.1	16.9	47.2	1.1	50.6	20.2	15.7	23.7	7.9	14.6	10.1
Wong & Cheung[66]	4	245		35.5	24.1	4.1	35.1	33.9	13.1	2.4	3.7	0	1.8	.8	0
	5	270		70.7	31.9	0	41.5	43.7	23	7.4	5.2	1.5	42.2	2.2	1.5
	6	167		73.1	37.7	1.2	49.1	59.9	37.7	7.2	18	5.4	63.5	1.8	12
	7	127		84.3	77.2	7.1	48.8	74.8	59.1	33.9	38.6	12.6	33.9	3.1	3.9
	8	89		96.6	77.5	9	42.7	78.7	74.2	37.1	46.1	18	36	13.5	3.4
	9	108		88.9	74.1	12	72.2	80.6	67.6	38.9	47.2	10.2	59.3	7.4	14.8
	10	107		91.6	77.6	9.3	83.2	86	60.7	46.7	62.6	14	59.8	14	17.8

Table 4.12: Weighted frequency of the proportion of children achieving mastery in each of the 12 FMS

	% Mastery											
	Run	**Gallop**	**Hop**	**Leap**	**Jump**	**Slide**	**Strike**	**Dribble**	**Catch**	**Kick**	**Throw**	**Roll**
4y	35.5	24.1	4.1	35.1	33.9	13.1	2.4	3.7	0.0	1.6	0.8	0.0
n	245	245	245	245	245	245	245	245	245	245	245	245
5y	70.7	31.9	0.0	41.5	43.7	23.0	74.1	51.9	1.5	42.2	2.2	1.5
n	270	270	270	270	270	270	270	270	270	270	270	270
6y	74.8	50.4	6.9	45.8	38.9	34.0	6.1	11.8	5.7	42.4	2.7	9.5
n	262	262	262	262	262	262	262	262	262	262	262	262
7y	83.6	78.3	6.6	48.0	63.2	54.6	28.9	32.2	10.5	30.3	3.9	4.6
n	152	152	152	152	152	152	152	152	152	152	152	152
8y	90.3	77.4	11.3	41.1	58.9	66.9	30.6	38.7	21.8	29.8	11.3	4.8
n	124	124	124	124	124	124	124	124	124	124	124	124
9y	84.8	78.2	14.2	60.9	44.7	59.9	30.5	33.0	16.2	36.0	10.7	12.7
n	197	197	197	197	197	197	197	197	197	197	197	197
10y	91.6	77.6	9.3	83.2	86.0	60.7	46.7	62.6	14.0	59.8	14.0	17.8
n	107	107	107	107	107	107	107	107	107	107	107	107
4-8y	64.7	42.6	4.1	42.1	42.9	28.6	28.6	24.7	3.8	29.6	2.3	3.9
n	929	929	929	929	929	929	929	929	929	929	929	929
8-13y	88.1	77.8	12.1	60.7	59.1	62.1	34.6	42.1	17.3	40.2	11.7	11.7
n	428	428	428	428	428	428	428	428	428	428	428	428
4-13y	72.1	53.7	6.6	48.0	48.0	39.2	32.9	30.1	15.5	35.8	10.4	6.3
n	1357	1357	1357	1357	1357	1528	1357	1357	1528	1528	1528	1357

4.5 Discussion

This paper is the first systematic literature review that has examined the FMS proficiency levels of primary school aged children worldwide, assessed via the TGMD-2. It provides a collation of FMS proficiency of over 8000 primary school aged children, from 16 countries and six continents. Analysis produced mean scores (raw scores, standard scores, GMQ and percentiles) across all relevant studies representing the FMS levels of each respective age group (4-13 years) as well as representing the levels of younger children (4-8 years), older children (8-13 years) and all primary school aged children (4-13 years). Children's FMS levels were found to be higher among older children and among the older age range in comparison to the younger ages and age range. These higher scores may result from a combination of natural maturation and additional quality FMS instruction, feedback as well as practice opportunities, during the additional life years.[69] At each respective age (and age range), children exhibited higher LOCO proficiency than OC proficiency. Furthermore, the throw and roll (both object-control skills) were found to be among the least proficient skills across all age groups and ranges. This supports the suggestion that greater instruction and practice are needed for object-control skills than locomotor skills due to the greater perceptual demand and complexity of the object-control skill components.[30] With regard to standardised scores based on age and sex, SS and GMQ (weighted mean scores), children worldwide demonstrate *average* FMS levels when compared with TGMD-2 norms,[32] which would suggest that FMS levels have remained static over the last 15 years. However, among the older cohort (8-13 years), 26.6% of children were classified as *poor* (the highest proportion of children from this age category), in contrast to only 7% of the TGMD-2 normative sample.[32] As GMQ is derived based on age (and sex), and while the younger age range exhibited *average* FMS levels, the 8-13 years age range may not have received the quality instruction and feedback or opportunities for FMS practice to improve their FMS levels, relative to the increase in age. These results highlight the large potential for FMS development among primary school aged children.

To improve FMS levels among children, (i) quality instruction in teaching the skills,[25,70] (ii) practice time undertaken by children and (iii) feedback are all essential elements.[1]

Recent systematic reviews on the effectiveness of fundamental movement skill interventions among youth populations revealed that such intervention programmes have the potential to significantly improve FMS proficiency in this cohort.[2,30] A large effect size for overall (standardised mean error = 1.42) and locomotor (*standardised mean error* = 1.42) proficiency were reported following such interventions, with a medium effect size (*standardised mean error* = .63) reported for object-control proficiency.[30] As children have the potential to master FMS by the age of 5-7,[1] and have been shown to improve FMS greatly at a young age,[25] it is important that all proposed interventions are introduced as early as possible. Thus, based on the current worldwide levels which indicate the potential scope for improvement, FMS interventions that have been found to improve FMS greatly at a young age[25] should be implemented in early education settings, including primary schools, to enhance the FMS levels of children.

The primary school setting offers an ideal opportunity for the development of FMS, with Physical Education (PE) identified as one of the most influential factors.[71] During the primary school years, children spend approximately 40% of their waking day in the school setting, throughout the academic year. In addition, primary schools often possess the necessary resources (including teachers but also facilities and equipment), scope within the PE curriculum and access to all attending children to facilitate FMS development.[72,73] As quality instruction, practice opportunities and feedback are essential elements for FMS development, FMS knowledge and education are imperative for the teachers, club coaches, parents and significant others, with research indicating extensive FMS training and support can positively impact FMS proficiency of children.[25,74]

It is reported that motor skill interventions most consistently associated with improvements in FMS include those adopting a multi-disciplinary approach, of long duration (> 6 months), providing multiple sessions per week, delivered by a PE specialist and supported by parental involvement (e.g. 'at home' practice assisted or supervised by parents, parent evenings).[31] The introduction of after-school (or alternatively lunchtime or before school) multi-skills clubs has also been found to be effective in improving FMS[2] in addition to those involving community engagement.[75,76] Based on the evidence presented in this review that highlights the substantial scope for improvement in FMS proficiency levels, interventions incorporating these aforementioned approaches may be required to develop these movement skills.

Given the existent reciprocal relationship between FMS and PA[77] and the associated health benefits (physical, psychological and social),[6] this review serves to provide a valuable insight, and may guide education and health authorities, in developing policies and strategies to improve PA and sport participation levels as well as the overall health and well-being of children. With physical inactivity identified as the fourth leading risk factor for global mortality,[78] any improvement in the FMS levels of children may help increase PA levels and thus ease the global physical inactivity crisis.[79] An increase in FMS proficiency may also combat the rise in overweight/obesity levels worldwide, which have dramatically increased from 4% in 1975 to over 18% (340 million) in 2016 among children and adolescents.[80]

Future Recommendations

For all future research, it is recommended that standardised scores (subset and GMQ) and raw skill scores must be reported when FMS proficiency levels using the TGMD-2 are presented to allow comparisons across this research domain. As is evident in the current review, those studies that did not report either some/all of the respective scores could not be used to make comparisons with studies that did. The reporting of standardised scores are recommended as per the guidelines of Ulrich[32]; they provide the clearest indication of FMS proficiency (locomotor, object-control or overall), accounting for age and sex. The reporting of raw scores (subset and skill) are also important as they provide information relating to proficiency in each of the individual skills, which may highlight specific skills that children are weak/strong in and which may require attention.

A further recommendation is the introduction of a formal annual assessment of FMS proficiency among primary school aged children to monitor the development of children's movement skills. It has been found that formative assessment in primary PE can enhance the quality of teaching and learning. The inclusion of formal assessment may aid in the structuring and planning of lessons, the formulation of quality feedback and direct future planning.[81] Therefore, the formal assessment suggested in the current research will further assist teachers as well as education and health authorities in the attempt to facilitate the holistic development of each child. It will also provide for accurate comparisons of FMS proficiency levels to be made across different ages and countries. Longitudinal research and long-term follow-up studies are also recommended to allow trends and patterns in FMS development to be established.

Strengths and Limitations

Strengths of this review include: (i) the use of a systematic search strategy across several databases, (ii) an extensive study detail extraction, (iii) an alignment with the PRISMA statement and (iv) the inclusion of FMS proficiency levels across 16 different countries. To date, no systematic review of the FMS proficiency levels of children worldwide has been conducted. Although, a number of tools have been used in the research to evaluate children's FMS proficiency worldwide, the TGMD-2 was selected for use in the current research as it is a criterion- and norm-referenced FMS assessment tool. Furthermore, the tool is validated among 3-10 year olds and widely used to assess children's FMS proficiency worldwide. While the systematic literature review conducted in this research is limited in that FMS assessment using the TGMD-2 was an inclusion criteria, future research should conduct a systematic literature review including literature that reports the results of FMS examinations using a wide range of FMS assessment tools. Other limitations include: (i) the exclusion of studies published prior to 2003, (ii) only studies published in English were included, (iii) studies including participants from special populations (e.g. low SES, children with disabilities/disorders, volleyball players) were not included and (iv) a small sample size was used in the calculation of several weighted mean scores due to the limited number of studies reporting the respective scores. While the current systematic literature review collated data from primary school children worldwide, future research may examine differences in FMS proficiency levels between countries or investigate sex-related differences in FMS proficiency worldwide.

4.6 Conclusion

Raw scores (weighted mean scores) indicate that movement skill proficiency is greater among older children than younger children. Based on standardised scores, SS and GMQ (weighted mean scores), children worldwide demonstrate *average* FMS levels when compared with normative data collected in 1997-1998, presented in the TGMD-2 manual.[32] However, as primary school aged children worldwide have the potential to correctly perform basic movement skills by the age of seven, it is evident that large opportunity and scope for improvement in all FMS, among all ages including the older age groups, remains.

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While the current chapter provided a systematic review of the current FMS levels worldwide, the next chapter will evaluate the current FMS levels of a cohort of Irish primary school children. Age and sex-related differences in FMS proficiency among this cohort are also investigated. Furthermore, the FMS level of Irish primary school children is compared to that of international counterparts.

Chapter 5:

Age and sex differences in Fundamental Movement Skills among a cohort of Irish school children

5.1 Abstract

Introduction: The purpose of this study was to assess fundamental movement skill (FMS) proficiency of Irish primary school children, relative to age and sex. Data collected were baseline measures for *Project Spraoi*, a physical activity (PA) and nutrition-based intervention.

Methods: Participants (*N*=203) were senior infant (*n*=102, mean age: 6.0 ± .4 years) and fourth class (*n*=101, mean age: 9.9 ± .4 years) children from three primary schools in the south of Ireland. FMS testing was conducted using the Test of Gross Motor Development-2 (TGMD-2), assessing six locomotor and six object-control skills. Analysis of variance (ANOVA) was used to assess age and sex related differences in FMS proficiency.

Results: Older children scored significantly higher than younger children in both locomotor ($p < .05$) and object-control score ($p < .05$). Boys scored significantly higher than girls in object-control score ($p < .05$), while girls scored significantly higher in locomotor score ($p < .05$).

Conclusion: FMS levels among Irish primary school children are similar to children worldwide, with age and sex differences evident. Early interventions, aimed at improving FMS, are warranted among Irish primary school aged children as greater proficiency is related to greater PA participation and numerous health benefits.

KEYWORDS: physical activity, motor learning, pediatrics, motor development

5.2 Introduction

Fundamental movement skills (FMS) are basic observable patterns of movement; these include running, jumping, hopping, throwing, catching and striking among others (Gallahue & Ozmun, 2006). FMS are regarded as the building blocks upon which more complex, sport specific movements are based, and have been found to be related to greater participation in physical activity and sport (Gallahue & Ozmun, 2006; Logan et al., 2011). They are often categorised into locomotor skills involving the movement of the body from one location to another (e.g. running and jumping), object-control skills involving the manipulation of an object (e.g. throwing and kicking) and stability skills (e.g. balancing and twisting) (Lubans et al., 2010).

Gallahue and Ozmun's (2006) hourglass model for motor skill development suggests that both boys and girls have the potential to demonstrate mastery of FMS (i.e. perform the skill(s) correctly) between the ages of five and seven years. To achieve such mastery, these skills must be learned and practiced; they are not acquired naturally (Pang & Fong 2009). Therefore, the early years (± 3-7 years) are a critical period in the development of these skills (Gallahue et al., 2012).

FMS proficiency in childhood has been associated with numerous benefits including higher levels of habitual physical activity (Holfelder & Schott 2014), physical fitness among both children and adolescents (Cattuzzo et al., 2016; Lubans et al., 2010) and a more favourable body composition and weight status (Barnett, van Beurden et al., 2008; Lubans et al. 2010). FMS proficiency is also associated with more efficient cognitive functioning and academic performance (Haapala, 2013). Therefore, FMS development among children has the potential to positively impact the holistic development, health and well-being of young people (Barnett, Stodden et al., 2016; Lubans et al., 2010).

Both age and sex have been found to influence FMS proficiency among children (Bardid et al., 2016; Bryant et al., 2014; Freitas et al., 2015; Spessato et al., 2013). Older children typically exhibit superior FMS proficiency than their younger counterparts (Bardid et al., 2016; Freitas et al., 2015; Mitchell et al., 2013, Spessato, Gabbard, Valentini, Rudisill,

2013) as a result of natural maturation and additional instruction, practice and feedback (Charlesworth, 2016).

Boys have commonly been found to demonstrate higher levels of overall FMS compared to girls (Barnett et al., 2009; Barnett, van Beurden et al., 2008; Charlesworth, 2016; Cohen, Morgan, Plotnikoff, Callister et al., 2015), although some studies have reported no sex-related differences within overall FMS performance (Hardy, King, Farrell, et al., 2010; Kordi et al., 2012).

Sex differences in FMS proficiency have predominantly been explained by the type of activities that children undertake, with boys and girls possessing very similar biological characteristics such as genotype, body composition, strength and limb length prior to puberty (Malina et al., 2004). These activities that boys and girls engage in are largely influenced by social and environmental factors such as the influence of family, peers, teachers and the physical environment (Booth et al., 1999; Hardy, King, Farrell, et al., 2010; Thomas & French, 1985), with boys participating more in ball sports (object-control related activities) while girls participate more in dance and gymnastics (locomotor related activities) (Bardid et al., 2016; Booth et al., 1996, 2006; Hardy, King, Farrell, et al., 2010).

As a result, many studies have found that boys have greater object-control proficiency (Bardid et al., 2016; Booth et al., 2006; Hardy, King, Farrell, et al., 2010; Lubans et al., 2010; Spessato, Gabbard, Valentini et al., 2013; van Beurden et al., 2002) than girls, while some studies have reported no sex-related differences in object-control proficiency (Bakhtiar, 2014; Bryant et al., 2014; Hardy, King, Farrell, et al., 2010; Kordi et al., 2012; van Beurden et al., 2002) among children. In relation to locomotor skill proficiency, while there are inconsistent findings, with some research reporting no sex difference (Bakhtiar, 2014; Barnett, van Beurden et al., 2008; Kordi et al., 2012; van Beurden et al., 2002), others have found that girls perform significantly better than boys at these skills (Barnett et al., 2009).

Current FMS proficiency levels of children worldwide have been reported to be low (Bardid et al., 2016; Bellows et al., 2013; Bryant et al., 2014; Cliff et al., 2009; Khodaverdi & Bahram, 2015; Kordi et al., 2012; Mitchell et al., 2013; Spessato, Gabbard, Valentini et al., 2013). Recent studies and trends indicate lower FMS proficiency among children when compared to a previous generation (Bardid et al., 2016; Spessato, Gabbard, Valentini et al., 2013). The Test of Gross Motor Development-2 (Ulrich, 2000), commonly referred to as the TGMD-2 is a process oriented FMS assessment tool. Normative data expressed as a Gross Motor Quotient (GMQ) has been developed using data collected in 1997-1998 among a large cohort (*n*=1208) of 3- to 10-year-old US children (Ulrich, 2000). Based on mean GMQ, the FMS proficiency of a cohort of 3- to 6-year-old Belgian children (Bardid et al., 2016) pre-school children from the US (Bellows et al., 2013) and pre-school girls in Australia (Cliff et al., 2009) have been categorised as *average*. However, lower FMS levels have also been reported with a *below average* GMQ found among 7- and 8-year-old Belgian children (Bardid et al., 2016), 6- to 10-year-old Canadian children (Burrows et al., 2014) and Australian pre-school boys (Cliff et al., 2009), while *poor* FMS levels have been exhibited among 9-year-old Iranian girls (Khodaverdi & Bahram, 2015).

FMS proficiency has also been reported worldwide in terms of mastery levels. Mastery is achieved when all required criteria associated with a skill are demonstrated by the participant. International levels of FMS mastery have also been reported to be low (Bryant et al., 2014; Mitchell et al., 2013; Valentini et al., 2016). Mitchell et al. (2013) found that the proportion of 5- to 12-year-old New Zealand children who demonstrated mastery did not exceed 65% for eight out of the 10 skills assessed via the TGMD (the run and slide being the two exceptions), with the kick (21%), throw (31%) and strike (40%) among the least proficient skills. Furthermore, less than 40% of British children aged 6- to 11-years-old, achieved mastery in eight similar skills (sprint, hop, gallop, balance, jump, catch, throw and kick) assessed using the 'Move It Groove It' assessment tool (Bryant et al., 2014).

To date, no published research exists that has examined FMS levels among Irish primary school children. While a study including the assessment of FMS in Northern Ireland was conducted by Breslin et al. (2012), the scoring protocol of the adapted tool developed was not described nor were the current levels among the cohort reported. International comparisons reveal that Irish children have low PA levels as well as high levels of sedentary behaviour (Tremblay, 2014). Furthermore, according to a WHO study involving 53 European countries, Ireland has been predicted to be the fattest of these nations by 2030 (Webber et al., 2014) and thus, an investigation into the FMS levels of Irish children may highlight FMS as an area with the potential for improvement. Based on the associations between FMS and numerous benefits, improving FMS may be one such mechanism to help promote health and wellbeing and combat the rise in obesity that has been predicted in our country (Webber et al., 2014). Therefore, the aim of this research was to examine the current FMS proficiency levels among Irish primary school children, as well as to investigate any age- and sex-related differences that may exist among this cohort. Based on the declining trend that is apparent in FMS proficiency, it is hypothesised that Irish primary school children will demonstrate similarly low levels to those reported among children worldwide in recent literature, irrespective of cultural and sporting habits.

Furthermore, it is hypothesised that older children will demonstrate greater FMS proficiency than the younger cohort and that boys will have greater object-control proficiency than girls.

5.3 Methods

Participants

Data collection was conducted as part of baseline measurements for *Project Spraoi*, a primary school-based physical activity and nutrition intervention project (Coppinger et al., 2016). Three primary schools (one rural mixed and two urban single sex: one boys and one girls) from a region in southern Ireland were invited to partake in the project.

Ethical approval was obtained from Cork Institute of Technology Research Ethics Review Board. From a total of 301 eligible children from senior infants and fourth class, written informed parental consent for involvement in the study was provided and returned for 203 children (110 boys, 54.2% and 93 girls, 45.8%) (67% consent rate). Of the 203 participating children, 102 were from senior infants (mean age: 6.0 ± .4 years) and 101 from fourth class (mean age: 9.9 ± .4 years).

Anthropometric Measures

Anthropometric data were collected prior to FMS assessment. Height was measured to an accuracy of .1cm using a Leicester portable height scales. Body mass was measured to an accuracy of .1kg, using a Tanita WB100MZ portable electronic scale. Shoes were removed for both measures. BMI was calculated as weight (kg) divided by height (m^2). Children were classified into BMI categories (i.e. normal, overweight/obese) using age and sex-specific cut-off points developed by Cole et al. (2000).

FMS Assessment

FMS proficiency was measured using the Test of Gross Motor Development-2 (Ulrich, 2000). This FMS assessment instrument, which has been used worldwide to assess FMS proficiency among children (Bakhtiar, 2014; Burrows et al., 2014; Cliff et al., 2009; Hardy, King, Farrell, et al., 2010; Spessato, Gabbard, Valentini et al., 2013), is a criterion and norm-referenced, process-oriented tool that has been found to be both valid and reliable for use among children aged 3-10 years (Ulrich, 2000). The TGMD-2 consists of two subsets of skills; locomotor and object-control. The six locomotor skills assessed are the run, gallop, slide, leap, hop and horizontal jump. The six object-control skills assessed are the kick, catch, overhand throw, strike, underhand roll and dribble.

Data Collection

Data were collected over four days in October 2014, by a cohort of nine trained evaluators from the *Project Spraoi* Research Team (postgraduate researchers and staff of Cork Institute of Technology and University College Cork). Prior to testing, evaluators completed an FMS-testing training workshop which was delivered by a research practitioner with extensive experience of using the TGMD-2 (O’Brien et al., 2016). Testing of each class group (22-30 children) took approximately one hour and was carried out in a large, indoor sports hall. The testing procedure replicated the protocol used by previous researchers in an Irish school-context (O'Brien et al., 2016). The hall was divided into four stations with the following skills tested at each station: (i) run, leap, hop, gallop, slide (ii) catch, throw, roll (iii) kick, strike (iv) dribble and jump. Groups of 5-8 children were allocated to each station. When skills were completed at a station, the groups simultaneously rotated clockwise until all 12 skills had been evaluated. A demonstration of each skill was provided by an evaluator assigned to each station. Each child performed the skill three times, consisting of one familiarisation trial and two test trials. All trials were recorded using a video camera by an evaluator at the station. As each child performed the skill, their personal ID number (assigned prior to testing) was spoken into the camera. This ensured accuracy when assigning scores to each child's performance. This process was repeated for each of the 12 FMS.

Scoring Protocol

The videos of the test trials were uploaded to a laptop and analysed retrospectively. Each FMS consists of 3-5 behavioural components. If a component was performed correctly, a score of 1 was awarded. If it was performed incorrectly, a score of 0 was awarded. This procedure was carried out for each of the two test trials and scores from both trials were then summed to obtain a raw skill score (Ulrich, 2000). Locomotor and object-control subset scores were calculated by summing the raw scores of the individual skills within each subset (Locomotor Score Range:0-48; Object-control Score Range: 0-48). Subsequently, the Gross Motor Quotient (GMQ) was derived as outlined in the TGMD-2 and used to categorise the overall FMS performance of each child into one of seven categories, ranging from *very poor* to *very superior*. Children with a GMQ score below 70 are classified as *very poor*, those between 70-79 classified as *poor*, 80-89 as *below average*, 90-110 as *average*, 111-120 as *above average*, 121-130 as *superior* and those above 130 as *very superior* (Ulrich, 2000).

Inter- and intra-rater reliability was established between a research practitioner with extensive experience using the TGMD-2 and the two principal researchers conducting the video analysis. Inter- and intra-observer agreements were calculated for 10% of the sample, using the equation (agreements/ (agreements + disagreements)) x 100. The inter- and intra-reliability scores across the 12 FMS ranged from 86-99% agreement, all of which are greater than the recommended 85% threshold required to demonstrate reliability (Thomas et al., 2011).

Data Analysis

Children were divided into four sub-groups according to age and sex; 6-year-old boys, 6-year-old girls, 10-year-old boys and 10-year-old girls. Means and standard deviations were used to summarise the data. An analysis of variance (ANOVA) was undertaken to investigate differences across total FMS scores, locomotor subset scores and object-control scores with respect to age and sex. All statistically significant results were supported with the strength of the result, i.e. effect size (partial eta squared: small = .01; medium = .06; large = .14) (Cohen, 2013). Pairwise comparisons (using Tukey's test) were examined to identify significant interaction and main effects. Fisher's exact tests were carried out to investigate if statistically significant differences existed across the number of FMS mastered by (i) age and (ii) sex, as well as the proportion of children achieving mastery in each FMS with respect to (i) age and (ii) sex. One sample t-tests were carried out to compare mean age and sex specific subset scores with those of a US reference sample included in the TGMD-2 manual (Ulrich, 2000). One sample t-tests were also used to compare mean GMQ scores with normative data (Ulrich, 2000). Finally, the distribution of the Irish sample across the performance categories for GMQ was compared to the distribution of the normative sample using a Chi-square test of independence to investigate if statistical significant differences existed. Subsequently, Fisher's exact test of independence were conducted to compare the distribution between countries in each category, controlling for multiple comparisons using the Bonferroni correction method (McDonald, 2014). When conducting the Fisher's exact test of independence for each individual category, the two variables were 'sample' (i.e. either Irish sample OR US normative sample) and 'classification' (i.e. classified in this category OR not classified in this category. The alpha level required for significance for all tests was set at $p < .05$.

5.4 Results

Table 5.1 presents anthropometric data, mean locomotor and object-control subset scores as well as mean GMQ scores, categorised by age and sex. Similar anthropometric measures were observed for both boys and girls within each age group ($p > .05$).

Table 5.1: Characteristics, mean subset scores and gross motor quotient (GMQ) scores (of the study sample (Mean ± SD)

	6 years		10 years	
	Boys	**Girls**	**Boys**	**Girls**
N	52	50	58	43
Age (years)	5.9 ± .9	6.0 ± .4	10.0 ± .4	9.8 ± .4
Height (cm)	116.0 ± 4.9	115.1 ± 5.8	140.6 ± 4.9	140.2 ± 6.3
Mass (kg)	21.7 ± 3.3	21.1 ± 2.8	35.7 ± 6.9	35.9 ± 7.3
Body Mass Index (BMI)	16.0 ± 1.6	15.9 ± 1.6	17.9 ± 2.5	18.1 ± 2.9
Overweight/Obese (%)	7.8	8.2	15.5	23.8
Locomotor Score (range: 0-48)	37.6 ± 4.2	40.3 ± 3.8	41.2 ± 3.5	41.9 ± 4.0
Object-control Score (range: 0-48)	32.0 ± 4.9	26.0 ± 4.8	40.3 ± 3.5	37.4 ± 4.3
GMQ (range: 46-160)	97.7 ± 7.2	100.9 ± 10.3	87.5 ± 9.0	92.3 ± 9.3

Age and Sex Comparisons of FMS Subset Scores

Results of the ANOVA (which yielded similar results when clustering by school) are presented in Table 5.2. Analysis revealed a significant age effect for both locomotor and object-control subset scores. It was found that 10-year-old children scored higher than their younger counterparts in both locomotor (medium to large effect size) and object-control subset scores (large effect size) (Table 5.2).

A significant main effect for sex was also found, with girls scoring higher than boys in locomotor score (small effect size) while boys scored significantly higher than girls in object-control score (large effect size) (Table 5.2).

No significant interaction effect was found for locomotor score. However, results revealed a significant interaction between age and sex for object-control scores (Table 5.2). Both 10-year-old boys and 10-year-old girls scored significantly higher than their 6-year-old counterparts in object-control subset score ($p < .05$). Also, among both 6-year-old and the 10-year-old cohorts, boys scored significantly higher than girls in object-control score ($p < .05$).

Table 5.2: Main and interaction effects for age and sex

	F	p	Effect size	F*	*p**	Effect size*
Main Effects						
Age						
Locomotor Score	22.200	<.001	.100	22.860	<.001	.105
Object-control Score	257.787	<.001	.564	267.337	<.001	.578
Sex						
Locomotor Score	9.662	.002	.046	4.398	.005	.063
Object-control Score	51.967	<.001	.207	20.683	<.001	.241
Interaction Effects						
Locomotor Score	3.145	.078	.016	2.355	.073	.035
Object-control Score	6.354	.012	.031	4.098	.008	.059

* account for clustering by school

Mastery Levels across Age and Sex

No child demonstrated mastery across all 12 FMS, with only one child (girl, 10 years) achieving mastery across 10 FMS. One girl (10 years) achieved mastery in all six locomotor skills while one boy (10 years) achieved mastery in all six object-control skills. No 6-year-old child achieved mastery in more than six FMS. All children did achieve mastery in at least one of the 12 FMS. Fisher's exact tests between FMS and age revealed a clear trend for higher levels of mastery in multiple skills (two or more skills) among 10-year-old children compared to the 6-year-old children, with a significantly larger proportion of 10-year-olds achieving mastery in two, three, four, five, six, seven and eight of the skills when compared to their younger counterparts, $p < .05$ (Figure 5.1). Fisher's exact tests between FMS mastery and sex, revealed that there was no significant difference in the number of skills mastered by boys and girls.

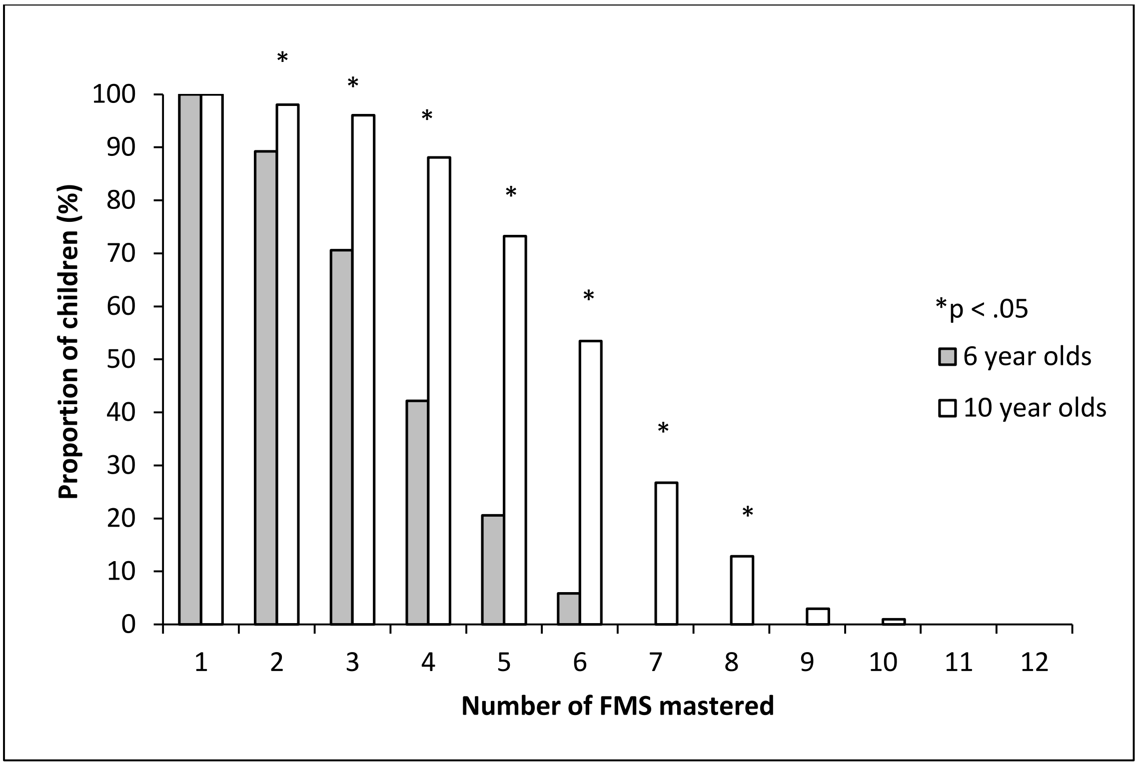

Figure 5.1: Number of FMS mastered by age group

Locomotor Skills

Mastery levels (%) were highest in the run for both 6- (80.4%) and 10-year-olds (77.2%), while the jump was the locomotor skill in which mastery levels were the lowest for both cohorts (10.8 and 13.9% respectively) (Table 5.3). Analysis revealed significant differences in the mastery of two locomotor skills (gallop and hop), $p < .05$. For the gallop, (62.4% of 10-years-olds v 43.1% of 6-year-olds; $p < .05$, Fisher's exact test) and the hop (36.6% of 10-years-olds v 19.9% of 6-year-olds; $p < .05$, Fisher's exact test), 10-year-old children had significantly higher levels of mastery compared to 6-year-old children.

Mastery levels (%) were highest in the run for both boys (87.1%) and girls (71.8%), while the jump was the locomotor skill with the lowest levels of mastery for both sexes (11.8% for boys and 12.9% for girls) (Table 5.3). A Fisher's exact test revealed that a larger percentage of girls achieved mastery in the run ($p < .05$), when compared to boys.

Object-control Skills

The kick was the object-control skill with highest mastery levels among both 6- and 10-year-olds with 39.2% and 82.2% demonstrating mastery of this skill respectively (Table 5.3). The dribble was the object-control skill with the lowest levels of mastery among 6-year-olds with no child of this age achieving mastery. The roll was the skill that the 10-year-olds were least proficient at with 13.9% demonstrating mastery. In five of the six object-control skills (kick, dribble, catch, throw and roll), a significantly greater proportion of 10-year-olds achieved mastery than the 6-year-olds ($p < .05$, Fisher exact tests) (Table 5.3).

Table 5.3: Percentage achieving mastery in individual FMS by (i) age and (ii) sex

FMS	Boys (% mastery)	Girls (% mastery)	*p*-value	6-year-olds (% mastery)	10-years-olds (% mastery)	*p*-value
Locomotor						
Run	71.8	87.1	.010	80.4	77.2	.610
Gallop	48.2	58.1	.204	43.1	62.4	.008
Hop	24.5	32.3	.273	19.6	36.6	.008
Slide	40.0	48.4	.257	38.2	49.5	.121
Leap	51.8	65.6	.063	54.9	61.4	.394
Jump	11.8	12.9	.833	10.8	13.9	.529
Object-control						
Kick	77.3	40.9	<.001	39.2	82.2	<.001
Dribble	22.7	28.0	.420	.0	50.5	<.001
Catch	25.5	18.3	.239	5.9	38.6	<.001
Strike	18.2	21.5	.598	18.6	20.8	.727
Throw	41.8	18.3	<.001	16.7	45.5	<.001
Roll	12.7	1.1	.002	1.0	13.9	<.001

Mastery levels were highest in the kick for both boys (77.3%) and girls (40.9%) (Table 5.3). The object-control skill with the lowest mastery levels among this cohort was the roll, with 12.7% of boys and 1.1% of girls proficient. In three of the six object-control skills (the kick, throw and roll), a greater proportion of boys achieved mastery, when compared to girls ($p < .05$, Fisher's exact tests). No significant differences were found between boys and girls for the dribble, catch or strike.

Comparison with US Normative Sample

Figures 5.2 and 5.3 compares the mean locomotor and object-control subset score of the four groups in the current study with the age and sex matched counterparts from the US reference sample.

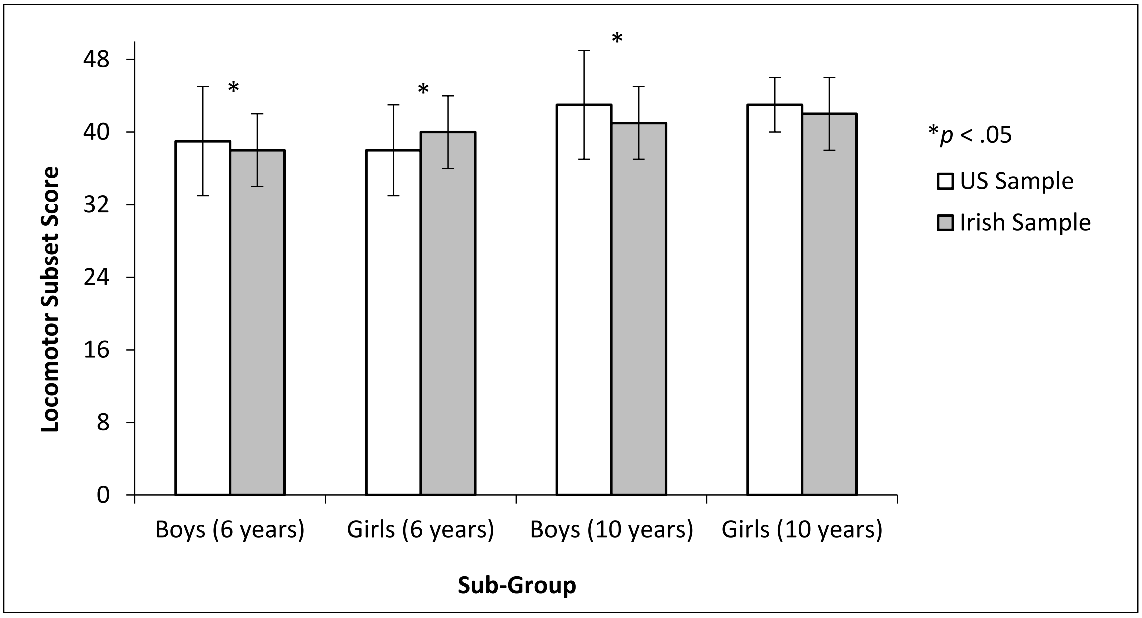

Figure 5.2: Comparison of locomotor subset scores (± standard deviation) between the Irish sample and US normative sample, by age and sex

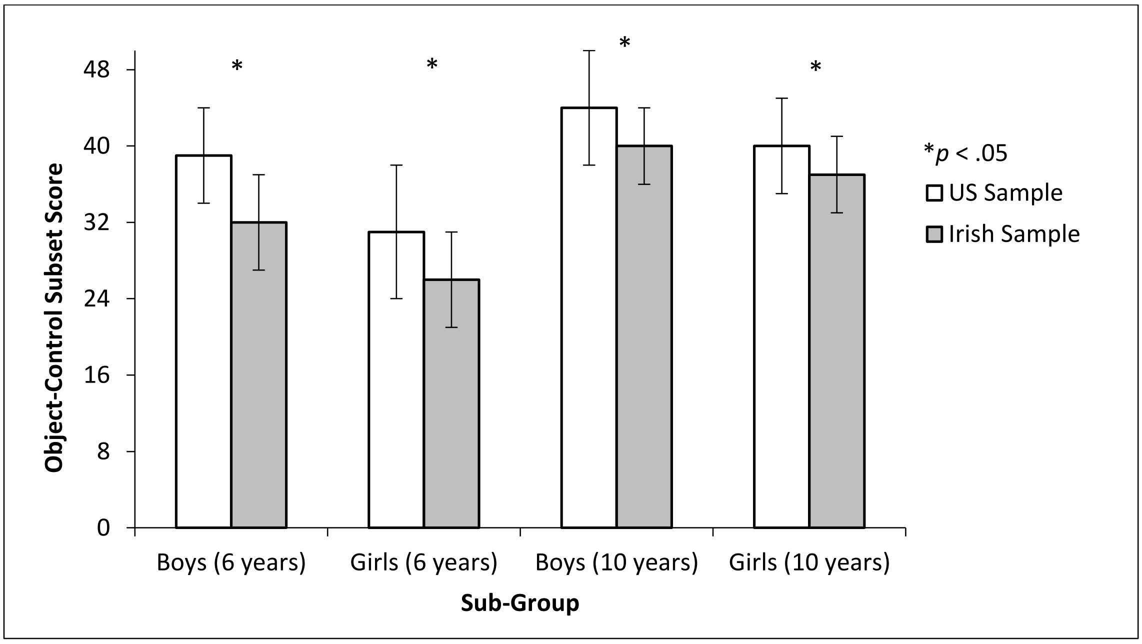

Figure 5.3: Comparison of object-control subset scores (± standard deviation) between the Irish sample and US normative sample, by age and sex

For locomotor score, both 6-year-old boys (t = -2.379, p = .021, *Cohen's d* = .33) and 10-year-old boys (t = - 4.051, p < .001, *Cohen's d* = .53) scored significantly lower than the US boys of similar ages. In contrast, 6-year-old girls demonstrated significantly superior locomotor proficiency compared to the normative data from US girls (t = 4.241, p < .001, *Cohen's d* = .60), while no difference existed between the cohorts of 10-year-old girls (*t* = -1.816, *p* = .077, *Cohen's d* = .28).

For object-control, significantly lower scores were found between all four groups compared to normative data from US children of similar age and sex. Significantly lower scores were found for 6-year-old boys (*t* = -10.403, *p* <.001, *Cohen's d* = 1.44), 6-year-old girls (*t* = -7.369, *p* < .001, *Cohen's d* = 1.04), 10-year-old boys (*t* = -8.157, *p* < .001, *Cohen's d* = 1.07) and 10-year-old girls (*t* = -3.973, *p* < .001, *Cohen's d* = 0.61).

When GMQ scores for the four groups were compared with the mean GMQ of the US sample (Figure 5.4), it was found that the 6-year-old boys scored significantly lower than the US norms (*t* = -2.305, *p* = .025, *Cohen's d* = .32), while no difference existed between 6-year-old girls and the US norms (*t* = .621, *p* = .538, *Cohen's d* = .09). Among the older cohort, significantly lower GMQ scores were found for both boys (*t* = -10.558, *p* < .001, *Cohen's d* = 1.39) and girls (*t* = -5.441, *p* < .001, *Cohen's d* = .83) compared with the reference sample.

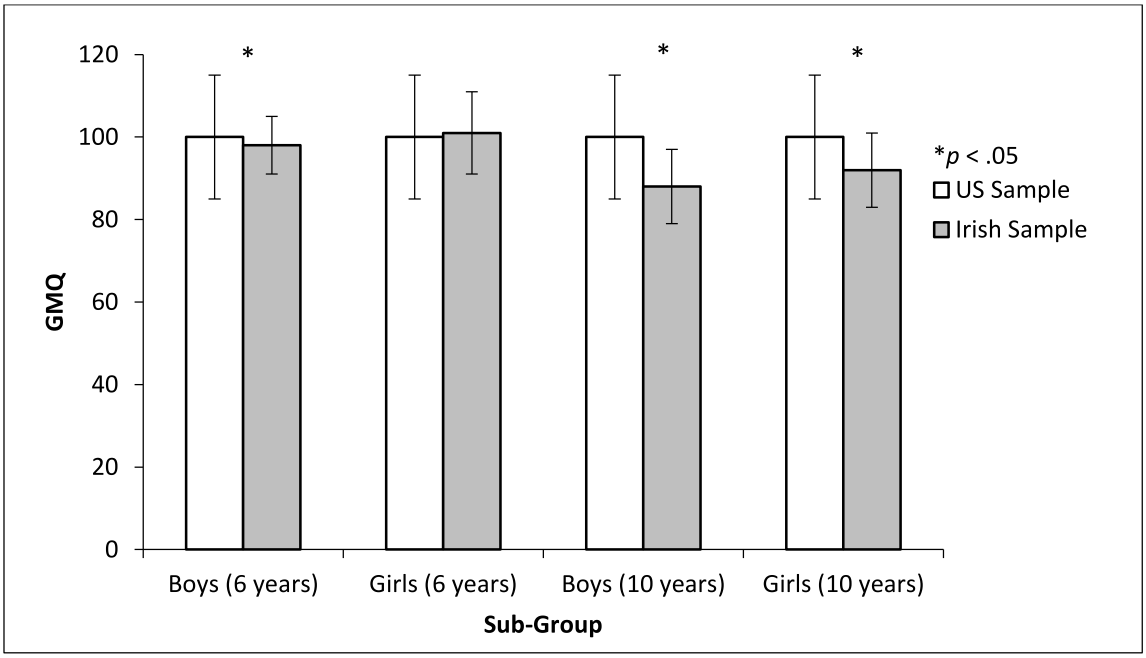

Figure 5.4: Comparison of GMQ (± standard deviation) scores between the Irish sample and US normative sample, by age and sex

Figure 5.5 shows a comparison of the distribution of the Irish sample with the US reference sample, across the seven performance categories as classified according to the TGMD-2 manual (Ulrich, 2000). A Chi-square test of independence revealed a significant difference when we compared the distribution of the Irish sample across the categories with the distribution of US sample (p < .001, Cramer's V = .172). At the lower end of the category scale, no significant differences existed across the *very poor* category, *poor* or *below average* category. However, there was a greater proportion of the Irish sample were classified as *average* compared to the US normative sample (*p* < .001, *Cramer's V* = .095). In contrast, at the upper end of the category scale, a significantly lower proportion of Irish children were classified in the *above average* (*p* < .001, *Cramer's V* = .111) and *superior* (*p* < .001, *Cramer's V* = .096) categories than the normative sample.

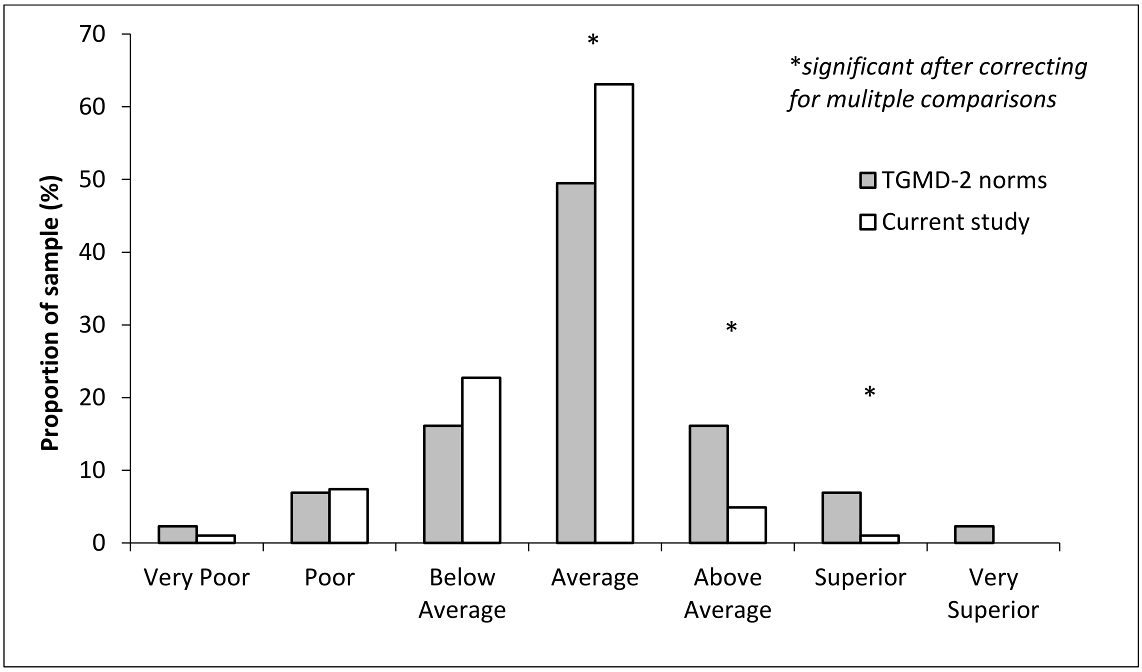

Figure 5.5: Distribution of GMQ score across TGMD-2 performance categories for Irish sample and US normative sample

5.5 Discussion

Age Comparisons of FMS Subset Scores

In this study, findings revealed that older children achieved higher performance scores than their younger counterparts in both locomotor and object-control subsets, independent of sex. This trend was also reported by many studies worldwide (Booth et al., 1999; Bryant et al., 2014; Mitchell et al., 2013; Spessato, Gabbard, Valentini et al., 2013) where it was reported that FMS proficiency increased with age.

In the six locomotor skills, a significantly greater proportion of 10-year-olds achieved mastery in the gallop and hop in comparison to their younger counterparts. In these two skills, the superior co-ordination and leg strength acquired with maturation by the older cohort may also have resulted in greater performances in contrast to the 6-year-olds.
In the object-control skills, a greater proportion of 10-year-olds achieved mastery in five of the six object-control skills (with the exception of the strike) compared with the 6-year-olds. These findings agree with those of several other studies (Bardid et al., 2016; Booth et al., 1999; Freitas et al., 2015), who also reported that object-control proficiency increases with age in children and follows the suggestion that a graded response should exist between FMS and age. Similarly, Bryant et al. (2014) found that year group had a significant effect on the throw and catch. Surprisingly, in the current study, no significant difference was found between the age groups for the strike. However, it must be noted that proficiency levels in the strike may be influenced by children's exposure to hurling/camogie (a striking sport, one of the national games of Ireland), which encourages a different hand-grip to that required by the TGMD-2.

The greater proficiency levels demonstrated by the 10-year-olds compared with the 6-year-olds can be attributed to several contributing factors including the greater instruction and coaching received from teachers, parents and coaches throughout the added years of life (which are still ahead of the 6-year-old cohort). Greater opportunities for feedback from such mentors during these years enable children to refine their techniques and abilities resulting in greater FMS proficiency. The additional practice time during these years experienced through PE lessons, extra-curricular activities, sport and physical activity engaged in outside of school as well as free play both at school and at home may also have contributed to the greater FMS ability of the older cohort.

The greater FMS levels of the older cohort also results, in part, from natural maturation including physical growth and greater strength relative to their body mass (Cohen, Morgan, Plotnikoff, Callister, et al., 2015) as well as the maturation of the nervous system (Charlesworth, 2016) enabling greater co-ordination and control of limbs. Although the older children demonstrated higher skill levels than their younger counterparts, potential for FMS improvement exists among this cohort (i.e. *mastery* was not attained).

Sex-related Comparisons of FMS Subset Scores

When subset scores were compared among boys and girls, it was found that girls outperformed the boys in locomotor score, independent of age. This is similar to previous studies (Barnett et al., 2009; Hardy, King, Farrell, et al., 2010) that reported gender differences among 4- to 5-year-olds (Hardy, King, Farrell, et al., 2010) and 8- to 10-year-old rural Australian children (Barnett et al., 2009). In the individual locomotor skills, mastery levels were higher among girls than boys in all six skills, with a significant difference in the run (p = .008). The greater locomotor proficiency among girls has been previously accounted for by the types of activities that girls are more likely to participate in such as dance and gymnastics, which have a greater emphasis on locomotor skills (Booth et al., 1999, 2006), a trend that is also evident in an Irish context (Woods et al., 2010). Further analysis revealed no significant difference in locomotor score between 10-year-old girls and boys which is similar to many studies worldwide (Bakhtiar, 2014; Kordi et al., 2012; van Beurden et al., 2002). This may be explained by the incorporation of the locomotor skills in a vast majority of sports and activities which children participate in during free play, physical education and sports.

The findings in the current study revealed a large effect size for boys outperforming the girls in the object-control score for both the 6-year-old and 10-year-old age group. These findings are in agreement with previous research among primary school children of all ages including 3- to 10-year-old Brazilian children (Spessato, Gabbard, Valentini et al., 2013), 7- to 10-year-old Portuguese children (Freitas et al., 2015) and among Australian primary school children (van Beurden et al., 2002).

The superiority of boys in object-control skills have been rationalised by the fact that boys participate in more sports/activities that involve object manipulation such as soccer and rugby than girls (Booth et al., 2006), a trend that is also evident among Irish primary school children with soccer, Gaelic Football, hurling, rugby and basketball among the most popular male sports (Williams et al., 2009; Woods et al., 2010). All of these sports/activities allow for greater exposure to, and practice of, these skills. In contrast, dance and swimming are among the most popular activities engaged in by girls in addition to drama and ballet (Williams et al., 2009; Woods et al., 2010); none of which focus on object-control skills. Furthermore, Irish boys have been reported to participate in extra-curricular activity more frequently than girls according to the CSPPA (The Children's Sport Participation and Physical Activity) study and this additional time is spent playing ball sports (Woods et al., 2010) which exposes them to further instruction, feedback than their female counterparts.

In the current study, even though both single-sex schools were limited with regard to space and facilities, the girls encountered additional limitations for PA in that they were not permitted to go outside during their first lunch break of the day nor were they permitted to run or use equipment (except skipping ropes) during the second lunch break. In contrast, the single-sex boys school and the mixed school cohorts participating in this study were permitted outside during all lunch breaks and had access to varied sports equipment (e.g. balls of various sizes etc.) providing greater opportunities to practice and develop FMS, especially object-control skills.

FMS Proficiency - A Global Comparison

FMS proficiency levels of Irish primary school children were found to be similar to levels reported worldwide (Bardid et al., 2016; Bellows et al., 2013; Burrows et al., 2014; Cliff et al., 2009; Spessato, Gabbard, Valentini et al., 2013; Ulrich, 2000). Mean GMQ score for 6-year-olds (boys and girls) and 10-year-old girls classified the FMS proficiency of these sub-groups in the *average* category, according to the TGMD-2 (ranging from 90-

110) (Ulrich, 2000). This is similar to findings by Bardid et al. (2016) in a study of 3- to 8-year-old Portuguese children (*n*=1614) in which *average* scores were recorded for the 3-, 4-, 5-, and 6-year-old cohorts, respectively. This was also found among 3- to 5-year-old children in Colorado (Bellows et al., 2013) and preschool girls in Australia (Cliff et al., 2009). In contrast, the 10-year-old boys in the current study scored *below average* (GMQ ranging 80-89) relative to Ulrich's normative dataset (Ulrich, 2000), similar to FMS proficiency among 3- to 10-year-old Brazilian children (*n*=1248) (Spessato, Gabbard, Valentini et al., 2013), preschool boys in Australia (Cliff et al., 2009) and 6- to 10-year-old Canadian children (Burrows et al., 2014), who also scored below TGMD-2 norms.

Mastery levels similar to those reported among New Zealand children (Mitchell et al., 2013) were exhibited in this study. The proportion of children achieving mastery was lower than those of the New Zealand children in the catch, dribble, strike, slide, jump and the hop (for age and sex). The kick was the only skill in which Irish children demonstrated greater proficiency than their southern hemisphere counterparts. In contrast, Irish children achieved higher mastery levels than 5- to 11-year-old Brazilian children in eight out of the 12 FMS assessed using the TGMD-2, with similar levels reported for the dribble, catch, roll and jump (Valentini et al., 2016).

In the current study, the locomotor skill with the highest mastery levels was the run. Similar findings were found among US, New Zealand and Brazilian children (Mitchell et al., 2013; Ulrich, 2000; Valentini et al., 2016). The jump was the locomotor skill with the lowest mastery levels in our sample, followed by the hop. Interestingly, the jump was also reported to be the least proficient locomotor skill by Mitchell et al. (2013), while the both the jump and hop were the locomotor skills with the lowest levels of mastery reported by Valentini et al. (2016). This may be explained by the complexity of these two skills as both involve a combination of physical challenge including strength for take-off, postural control as well as co-ordination and balance during flight and landing (Haibach, Reid, & Collier, 2011).

Among the cohort of Irish primary school children, the kick was the object-control skill with the highest mastery level. This may be explained by the high levels of participation in Gaelic football (a national game of Ireland involving kicking, catching and running) and soccer in Ireland (Woods et al., 2010). This is in contrast to Mitchell et al. (2013) who reported that the kick was among the least proficient object-control skills in New Zealand. The catch and dribble were among the best performed object-control skills among US and New Zealand children (Mitchell et al., 2013; Ulrich, 2000). As sports involving these skills are incorporated in to some of the most popular sports in the US (American football, basketball and baseball) (Wallerson, 2014) and New Zealand (rugby, cricket, basketball and netball) (Education in New Zealand, 2015), it is clear that sporting cultures have an influential role on FMS proficiency among young children.

In comparison to US normative data, the Irish sample demonstrated significantly lower locomotor, object-control and overall (as indicated by GMQ) FMS proficiency, with the exceptions of girl's locomotor ability. This exception may possibly be influenced by the restricted use of equipment during lunch times in the girls' school, which limited them to participate in locomotor activities only, during these times. Furthermore, it has been reported that dance (a locomotor activity) is the most popular extra-school sport and the second most popular extra-curricular activity among primary school girls in Ireland (Woods et al., 2010).

Cultural differences which exist between Ireland and US may contribute to object-control differences exhibited, with Gaelic Football, soccer and dance among the most popular sports among Irish primary school children (Woods et al., 2010) in contrast to basketball and baseball among the most popular sports in the US (Wallerson, 2014). However, lower FMS proficiency relative to this cohort may also have been due to the decrease in FMS ability and physical activity since data collection in the US sample (1997-1998). When classified into their respective performance categories, according to the TGMD-2, results revealed that a significantly greater proportion of Irish children than the US normative sample were categorised as *average*. Worryingly, a significantly lower proportion of children were categorised in the *above average* and *superior* categories than the US sample.

Many factors contribute to the low FMS levels exhibited among Irish primary school children relative to the US norms. These include low physical activity levels, with only 19% of children reaching the recommended 60 minutes of moderate-to-vigorous physical activity daily (Woods et al., 2010). Furthermore, the time spent in physical education (PE) in Irish primary schools is low. While the recommended level of weekly PE is 60 minutes, it has been reported that only 46 minutes per week PE is received by Irish primary school children (European Commission/EACEA/Eurydice, 2013). It has also been reported that Ireland spends less time in physical education in primary schools than all other EU countries (European Commission/EACEA/Eurydice, 2013). In contrast, US children (5- to 10-year-olds) are recommended to receive a minimum of 150 minutes instructional PE (National Association for Sport and Physical Activity, 1997). Although data collection was conducted in 1997-1998, US children, at that time, were recommended to receive daily physical education classes and it was found that elementary children received 50-200 minutes physical education weekly (National Association for Sport and Physical Activity, 1997). Furthermore, this physical education was delivered by a physical education specialist and/with the classroom teacher (National Association for Sport and Physical Activity, 1997) in contrast to the classroom teacher only in Ireland. Considering the reported low levels of both physical activity and PE participation among Irish primary school children (which is much lower compared to other European countries and the US), it is reasonable to suggest that the time devoted to FMS instruction and practice in Ireland is insufficient and it deserves greater prominence in the primary school curriculum.

Implications

To improve the current low FMS levels among Irish primary school children, quality instruction in teaching the skills (Mitchell et al., 2013; Morgan & Hansen, 2008), practice time undertaken by children and feedback are all essential elements (Gallahue & Ozmun, 2006).

Based on international best practice and research providing evidence for the effectiveness of motor skill development (Logan et al., 2011; Mitchell et al., 2013), FMS interventions should be carried out in early education settings including primary schools in Ireland to enhance the FMS levels of children.

A school-based multicomponent intervention involving principals, teachers, parents and specialised coaches similar to that which has been shown to be effective by Cohen, Morgan, Plotnikoff, Callister, et al. (2015) has the potential to improve the current levels of FMS in Ireland. The introduction of after-school (or alternatively lunchtime or before school) multi-skills clubs have also been found to be effective in improving FMS (Logan et al., 2011).

The introduction of an annual formal assessment of FMS of children may also be required to monitor proficiency levels among children over time, provide encouragement for primary school teachers to improve the FMS of children as well as to alert parents of certain skills which require further work and development. To date, Ireland is one of only three EU countries not to do so (European Commission/EACEA/Eurydice, 2013). An increase in the provision for FMS during PE time is recommended in the Irish PE curriculum as well as an increase in PE time allocated to each class to allow quality learning to take place.

To bridge sex-related differences that exist in both locomotor and object-control proficiency, it is important that boys and girls receive equal encouragement, instruction and opportunities to practice skills from both sub categories during PE, extra-curricular activity and free play from teachers, parents and peers (Spessato, Gabbard, Valentini et al., 2013).

As children have the potential to master FMS by the age of 5-7 (Gallahue & Ozmun, 2006) and have been shown to improve FMS greatly at a young age (Mitchell et al., 2013), it is important that all approaches are introduced as early as possible in primary school aged children.

Low FMS levels revealed in the current study and the existing high levels of overweight/obesity in Ireland based on international comparisons (Webber et al., 2014) highlight the need for FMS interventions in Irish primary schools to promote a favourable body composition and facilitate physical activity among many other associated health benefits. Such interventions may potentially combat the rise in obesity predicted for Ireland (Webber et al., 2014).

5.6 Conclusion

In conclusion, fundamental movement skill levels among Irish primary school children are similar to proficiency levels of children worldwide and have large scope for improvement. Older children score higher than their younger counterparts in both object-control and locomotor skills. Boys score higher than girls in object-control skills, while girls score higher in locomotor skills. This study provides reference data for future intervention studies, as well as related research exploring longitudinal trends in FMS among Irish primary school children. It also serves to provide comparative data with international studies with similar age- and sex-related cohorts. Knowledge of the FMS proficiency levels of Irish primary school children will aid teacher training colleges, national coaching bodies and parents to identify areas of weaknesses among Irish children and to target these in the school environment, coaching sessions, leisure activities and play time. Increases in physical activity levels, improvements in teacher expertise and targeted FMS school interventions are strategies with the potential to improve FMS proficiency among Irish primary school children and indeed worldwide.

Limitations

Limitations of this study include the low consent rate (67%), relatively small sample size and the small number of schools recruited for inclusion. While a small sample was involved in the current study, a wide range of the existing school types in Ireland participated, which included rural, urban, mixed sex, single sex girls and single sex boys schools. While our findings suggest that interventions to improve FMS are warranted to increase the proficiency levels among Irish primary school children, further investigation using a greater sample size across a wider geographical area in Ireland may provide further support.

The current study evaluated the FMS proficiency of a cohort of Irish primary school children. It also investigated age and sex-related differences in children's FMS proficiency, and compared Irish primary school children's FMS levels to those of counterparts from the US. While the current research assessed children's actual FMS competence, children's perceived FMS competence was also measured. The next chapter examines the accuracy of children's perceived FMS competence, and also investigates the relationship between perceived FMS competence and PA.

Chapter 6:

"I think I can, but can I?" The relationship between perceived and actual skill competence and physical activity

6.1 Abstract

Background: The investigation into the relationship between perceived (PC) and actual movement skill competence (AC) among children has yielded mixed results. A positive association exists between perceived physical competence and physical activity (PA), however few studies have examined the association between PC and PA. Therefore, this study (i) examines the relationships between children's PC and AC and (ii) PC and PA.

Methods: Data collected were part of *Project Spraoi*, a PA and nutrition-based intervention. Participants (N=419) were senior infant/1st class (n=202, mean age: 6.5 ± 0.6 years) and 4th/5th class (n=217, mean age: 10.4 ± 0.6 years) children from 3 schools in Cork, Ireland. The Test of Gross Motor Development-2 (TGMD-2) and Pictorial Scale of Perceived Movement Skill Competence for Young Children (PMSC) assessed actual and PC in six locomotor and six object-control FMS. Moderate-to-vigorous PA (MVPA) levels were measured by accelerometry. Wilcoxon signed-rank tests investigated differences between PC and AC scores. Hierarchical regression analysis was used to investigate the relationships between PC and both AC and MVPA.

Results: Children had greater object-control and total PC than AC. Among younger children, no difference was found between locomotor PC and AC, while older children had lower locomotor PC than AC. PC did not predict AC. Both object-control and total PC were significant predictors of MVPA.

Conclusion: Children have inflated perceptions of their overall and object-control movement skill competency. Perceived object-control and total FMS is associated with PA and thus, interventions aimed at increasing PA among children should target PC.

KEYWORDS: fundamental movement skill; perceived movement skill competence; school children; physical activity

6.2 Introduction

Fundamental movement skills (FMS) are the foundation upon which more complex sport specific skills are based, facilitating greater participation in physical activity (PA) and sport (Gallahue & Ozmun, 2006). They are often classified into 3 categories; locomotor skills involving the movement of the body from one location to another (e.g. running and jumping), object-control skills involving the manipulation of an object (e.g. throwing and kicking) and stability skills (e.g. balancing and twisting) (Lubans et al., 2010). The ability to perform FMS is associated with higher levels of habitual PA (Holfelder & Schott, 2014), physical fitness (Cattuzzo et al., 2016; Lubans et al., 2010) and more efficient cognitive functioning and academic performance (Haapala, 2013). FMS proficiency is also inversely associated with weight status (Barnett, van Beurden et al., 2008; Lubans et al., 2010).

Perceived movement competence, i.e. one's belief regarding his/her movement abilities, also influences one's engagement in PA (Stodden et al.,. 2008). It is proposed that children with high perceived competence in an activity/skill will persevere and pursue mastery in that activity/skill, while those with low perceived competence may disengage and lose interest in the activity/skill (Rudisill et al., 1993; Weiss & Amorose, 2005). Evidence supports the existence of a positive association between perceived competence and motivation to participate/continue participation in PA in children (Bagøien & Halvari, 2005), with perceived competence suggested to have greater influence than actual competence (Harter, 1978; 1982). In the conceptual model proposed by Stodden et al. (2008), perceived competence is proposed to be associated both actual motor competence and PA during early childhood. It is expected that this relationship strengthens with age, with a bidirectional relationship proposed to exist between PC and MC, as well as PC and PA during middle and late childhood (Stodden et al., 2008). These associations proposed by Stodden et al. (2008) have since been examined and supported (Robinson, Stodden, et al., 2015). Also, perceived competence is a known determinant of PA in older children and adolescents (Sallis et al., 2000). It has been found to mediate the relationship between childhood object-control proficiency and subsequent adolescent PA and fitness (Barnett, Morgan, van Beurden, & Beard,

2008) and is associated with a more favourable weight status among children (Jones, Okely, Caputi, & Cliff, 2010).

Perceived competence is formulated based on four psychological constructs; (i) past experiences, (ii) difficulty associated with the task, (iii) reinforcement and personal interaction with significant others and (iv) intrinsic motivation (Harter, 1978). Young children (<7 years of age) do not possess the required levels of cognitive functioning to evaluate past experiences, task difficulty or reinforcement from others (Piaget, 1959). They fail to accurately distinguish between actual competence and effort, commonly resulting in inflated levels of perceived competence (Harter, 1999). The inflated perceptions of motor skill competence observed during early childhood has the potential to drive actual motor skill competence, as those who perceive themselves as competent will persist and continue practice in that activity/skill which may lead to further FMS development and participation in PA (Robinson, Stodden et al., 2015). However, accuracy of perceptions increase as children age and cognitively develop (Harter, 1999). During middle childhood (8-11 years of age) children have a greater cognitive capacity and more accurate perceptions of motor competence are formulated based on comparisons made between their own ability and that of their peers (Harter, 1999). Therefore, perceptions of motor competence become more closely aligned with actual competence. Consequently, those with higher actual motor competence will have greater perceived motor competence resulting in greater mastery attempts, while those with lower actual competence will perceive skills/tasks as more difficult which may lead to fewer mastery attempts (Harter, 1999).

To date, the relationship between actual and perceived movement competence among primary school-aged children (4-13 years) has been moderately tested and mixed results have been reported (Robinson, Stodden, et al., 2015). Numerous studies have reported the existence of a positive relationship between actual and perceived competence during early childhood (LeGear et al., 2012; Robinson, 2011; Toftegaard-Stoeckel et al., 2010), while others have found no associations (Spessato, Gabbard, Robinson, & Valentini, 2013). However, few studies have used aligned assessment tools to evaluate perceived and actual competence (Barnett et al., 2017; Barnett, Ridgers, & Salmon, 2015; Liong et al., 2015; Slykerman et al., 2016), which is important if an accurate evaluation is to be obtained (Barnett, Ridgers, & Salmon, 2015; Liong et al., 2015). Studies using the Test of Gross Motor Development-2 (TGMD-2) (Ulrich, 2000) and the Pictorial Scale of Perceived Movement Skill Competence for Young Children (PMSC) (Barnett, Ridgers, Zask et al., 2015), assessing actual and perceived competence in 12 FMS, report weak positive correlations between perceived and actual object-control competence among cohorts of 4- to 8-year-old children (Barnett, Ridgers, & Salmon, 2015) and 5- to 8-year-old boys (Liong et al., 2015). However, no significant relationship was found between perceived and actual locomotor or total FMS competence by Liong et al. (2015). Similarly, a study among children of middle childhood age (9- to 11-year-olds), Barnett et al. (2017) found no significant association when comparing perceived and actual competence in locomotor, object-control or total FMS skills. It has been acknowledged that further research investigating this relationship using aligned measurement tools is required to ascertain if or how this relationship changes as children age (Robinson, Stodden et al., 2015).

A consistent positive association between perceived physical competence and PA in children has been reported, a relationship which has been extensively examined (Babic et al., 2014; Robinson, Stodden et al., 2015). However, few studies have investigated the relationship between perceived FMS competence and PA levels (Barnett et al., 2017; Barnett, Ridgers, & Salmon, 2015; Barnett, Salmon et al., 2016; Slykerman et al., 2016). Barnett et al. (2017) found no significant relationship between moderate-to-vigorous physical activity (MVPA) levels and perceived FMS competence among 9- to 11-year-olds, nor with perceived object-control competence among 4- to 8-year-old Australian children (Barnett, Ridgers, & Salmon, 2015). Similarly, Slykerman et al. (2016) found perceived skill scores were not significant predictors of MVPA among 5- to 8-year-old Australian children. In contrast, a longitudinal study by Barnett, Salmon et al. (2016) revealed that time spent in MVPA at 3.5 years predicted perceived FMS competence at five years of age, despite cross-sectional analysis at five years revealing no associations.

To date, there is limited research examining the relationships between (i) perceived and actual competence and (ii) perceived competence and PA among children, using aligned measures of assessment. Furthermore, there is no published research examining these relationships in a European context. Understanding these relationships is important as an overestimation of FMS competence may positively influence participation in PA and engagement in activities/sports that improve actual FMS. Conversely, an underestimation of FMS competence may have the opposite effect, resulting in disengagement and loss of interest in PA. Knowledge of the relationship between perceived and actual competence may aid the development of motor skill interventions to increase actual FMS competence and motivation to promote participation in PA. Therefore, the aims of this research were to investigate the relationship between (i) PC and AC and (ii) PC and PA levels among Irish primary school children.

6.3 Methods

Participants

In September and October 2015, data were collected as part of *Project Spraoi*, a primary school-based PA and nutrition intervention (Coppinger et al., 2016), by a team of trained evaluators. Ethical approval was obtained from Cork Institute of Technology Research Ethics Review Board. Children from senior infant, 1st, 4th and 5th classes from three primary schools (one rural mixed and two urban single sex: one boys and one girls) from a region in southern Ireland were invited to participate. Written informed parental consent for involvement in the study was obtained for 447 children (consent rate; 447/595; 75%). Only children present for actual and perceived competence were included in the study (*n*=419) (224 boys, 53.5% and 195 girls, 46.5%). Of these 419 children, 202 were from senior infant/1st class (mean age: 6.5 ± .6 years) and 217 from 4th/5th class (mean age: 10.4 ± .6 years).

Actual FMS competence

Actual FMS assessment was conducted across one school week using the TGMD-2 (Ulrich, 2000). This process-oriented assessment toolhas been found to be valid and reliable for use among 3- to 10-year-old children (Ulrich, 2000). The TGMD-2 consists of 12 FMS; six locomotor skills (run, gallop, slide, leap, hop and horizontal jump) and six object-control skills (kick, catch, overhand throw, strike, underhand roll and dribble). Each child performed the skill three times, consisting of one familiarisation trial and two test trials. All trials were recorded using a video camera and test trials were uploaded and analysed retrospectively. Each FMS consists of 3-5 behavioural components. If a component was performed correctly, a score of 1 was awarded. If it was performed incorrectly, a score of 0 was awarded. This procedure was carried out for two test trials and scores were then summed to obtain a raw skill score(Ulrich, 2000). Locomotor and object-control subset scores were calculated by summing the raw scores of the individual skills within each subset (Locomotor Score Range: 0-48; Object-control Score Range: 0-48). Subsequently, locomotor and object-control subset scores were summed to obtain a total FMS score (Range: 0-96). The testing procedure replicated the protocol used, and described in detail, previously (Bolger et al., 2017; O'Brien et al., 2016). Inter-rater reliability and intra-rater reliability was calculated for 10% of the sample, using the equation (agreements/(agreements + disagreements)) x 100. Inter-reliability (with a coder with extensive experience in FMS scoring) (O'Brien et al., 2016) and intra-reliability was established, with scores across all FMS exceeding 85% agreement (range:86-99%) (Thomas et al., 2011).

Perceived FMS Competence

The Perceived Movement Skill Competence for Young Children (PMSC) (Barnett, Ridgers, Zask, et al., 2015) was used to evaluate children's perceived competence (PC) in the 12 FMS assessed in the TGMD-2. This scale has acceptable face and construct validity, good test-retest reliability and internal consistency among children (Barnett, Ridgers, Zask et al., 2015; Barnett, Vazozu et al., 2016), and has been used in numerous countries (Barnett et al., 2017; Lopes, Barnett, Saraiva et al., 2016; Valentini et al., 2017). The PMSC was conducted individually in each school, during the week following the completion of the actual FMS assessment. For each skill, the children were shown two cartoon pictures, one of a child performing the skill competently and the other of a child performing the skill less competently. They were instructed to choose the picture they felt they were more like. If the chosen picture was that of the child who was 'pretty good', the child was asked whether they felt they were 'really good at…' (assigned a score of 4) or 'pretty good at…' (score of 3). If the chosen picture was that of the child who was ‘not so good’, the child was asked whether they felt they were ‘sort of good at …’ (score of 2) or ‘not so good at…’ (score of 1). Following this procedure, a score between 1 and 4 was obtained for each skill. Perceived locomotor (PC-LOCO) and perceived object-control (PC-OC) scores were calculated by summing the scores of the individual skills within each subset (PC-LOCO Range: 6-24; PC-OC Range: 6-24). Subsequently, PC-LOCO and PC-OC scores were summed to obtain a perceived total FMS (PC-TOTAL) score (Range: 12-48) (Barnett et al., 2015).

PA Measurement

PA levels were objectively assessed using triaxial ActiGraph GT3X+ accelerometers (Fort Walton Beach, FL, USA). Following actual FMS assessment, accelerometers were distributed to the children. Parents were reminded, via daily text messages, to ensure that children replaced their accelerometer each morning. Accelerometers were worn for seven consecutive days on the right hip during all waking hours (except when swimming, showering/bathing etc.). ActiLife software (version 6.13.3) was used in the data analysis. Inclusion criteria required wear time of ≥3 days of the week, with ≥600 minutes recorded per day, which has been shown to give adequate reliability and power among children (Riddoch et al., 2007). Of 228 children who received accelerometers, 182 (81%) met these requirements. A 5-second epoch length was used (Edwardson & Gorely, 2010). Periods of 20 minutes of consecutive zeros were indicated as non-wear time (Esliger et al., 2005). The first day of wear time was removed from the dataset to allow for subject reactivity (Esliger et al., 2005). The last day of wear time (i.e. Day 7) was also excluded from analysis. Cut points developed by Evenson et al. (2008), and validated by Trost et al. (2011), were used to compute average time spent in MVPA daily.

Data Analysis

Data were analysed using IBM SPSS Statistics for Windows (version 22.0). Children were divided into four sub-groups according to age and sex; 6-year-old boys, 6-year-old girls, 10-year-old boys and 10-year-old girls. Means and standard deviations were used to summarise the data. Wilcoxon signed-ranks tests were conducted to determine if a statistically significant difference existed between actual and PC scores for locomotor, object-control and total FMS (expressed as percentages of the maximum score possible for each test in Figures 6.1-6.3). Statistically significant results were supported with the effect size (*r:* small = 0.1, medium = 0.3, large = 0.5) (Cohen, 1988).

Hierarchical regression analysis was conducted, adjusting for age and sex, determining the relationship between PC scores (PC-LOCO, PC-OC and PC-TOTAL) and corresponding actual competence scores, respectively. Similarly, hierarchical regression analysis was conducted, adjusting for age and sex, investigating the proportion of variance in the PA levels (average daily MVPA) that could be explained by PC scores. The alpha level required for significance for all tests was $p < 0.05$.

6.4 Results

Table 6.1 presents mean actual and PC scores for each FMS subset as well as mean time engaged in MVPA for all sub-groups.

Table 6.1: Characteristics, actual and perceived subset scores and time spent in *average daily* MVPA (Mean ± SD)

	6-year-olds		**10-year-olds**	
	Boys (n=105)	**Girls (n=97)**	**Boys (n=120)**	**Girls (n=97)**
Age (years)	6.5 ± 0.58	6.4 ± 0.63	10.5 ± 0.63	10.4 ± 0.56
Actual LOCO (0-48)	38.3 ± 4.13	40.4 ± 3.29	42.0 ± 3.36	42.4 ± 3.57
(% of scale)	79.8 ± 8.60	84.2 ± 6.86	87.5 ± 6.99	88.3 ± 7.43
Actual OC (0-48)	26.7 ± 4.73	23.0 ± 4.07	30.5 ± 2.82	27.8 ± 4.11
(% of scale)	55.6 ± 9.85	47.9 ± 8.47	63.6 ± 5.88	57.8 ± 8.56
Actual TOTAL (0-96)	65.3 ± 6.90	63.5 ± 5.56	72.5 ± 4.85	70.1 ± 5.77
(% of scale)	68.0 ± 7.18	66.1 ± 5.79	75.5 ± 5.05	73.0 ± 6.01
PC-LOCO (0-24)	20.9 ± 2.94	21.6 ± 2.19	17.8 ± 2.68	17.9 ± 2.85
(% of scale)	87.1 ± 12.25	90.0 ± 9.13	74.2 ± 11.17	74.6 ± 11.88
PC-OC (0-24)	21.0 ± 2.87	19.8 ± 3.06	20.2 ± 2.35	18.6 ± 2.96
(% of scale)	87.5 ± 11.96	82.5 ± 12.75	84.2 ± 9.79	77.5 ± 12.33
PC-TOTAL (0-48)	41.9 ± 4.74	41.4 ± 4.57	38.1 ± 4.24	36.6 ± 4.76
(% of scale)	87.3 ± 9.88	86.3 ± 9.52	79.4 ± 8.83	76.3 ± 9.92
MVPA (minutes)	65.1 ± 22.10	58.8 ± 16.17	77.8 ± 21.79	52.9 ± 16.85

*****Actual LOCO: Locomotor score, Actual OC: Object-control score, Actual Total: Total FMS score, PC-Loco: Perceived Locomotor score, PC-OC: Perceived Object-control score, PC-Total: Perceived Total FMS score

Results from the Wilcoxon signed-ranks tests revealed that both 6-year-old boys and girls had greater PC-LOCO than actual locomotor competence. However, no significant difference was found (6-year-old boys: p = 0.051, 6-year-old girls: p = 0.078). In contrast, there was a significant difference between PC-LOCO and actual locomotor scores among 10-year-old boys (p < 0.001, ES: 0.58) and girls (p < 0.001, ES: 0.57), with both groups underestimating actual ability (Figure 6.1).

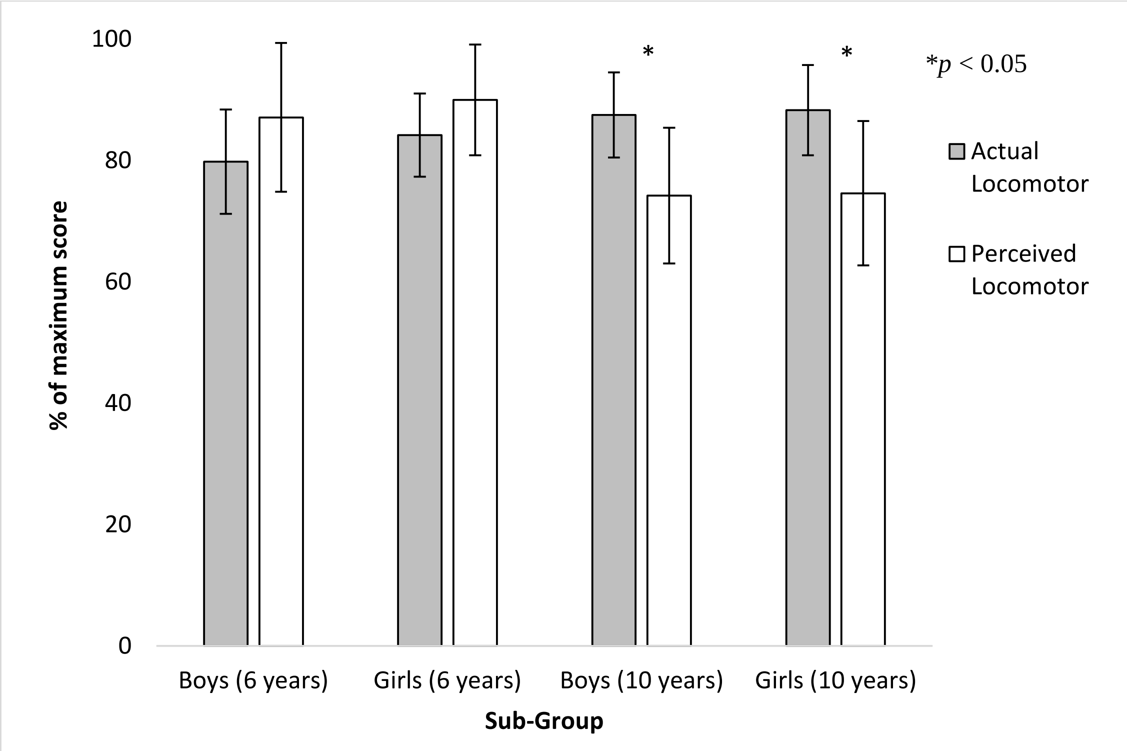

Figure 6.1: Perceived and actual locomotor competence (± standard deviation)

For object-control competence, significant differences were found between PC-OC and actual competence (p < 0.001 for all), with all sub-groups; 6-year-old boys (ES: 0.59), 6-year-old girls (ES: 0.60), 10-year-old boys (ES: 0.52) and 10-year-old girls (ES: 0.42) overestimating object-control proficiency (Figure 6.2).

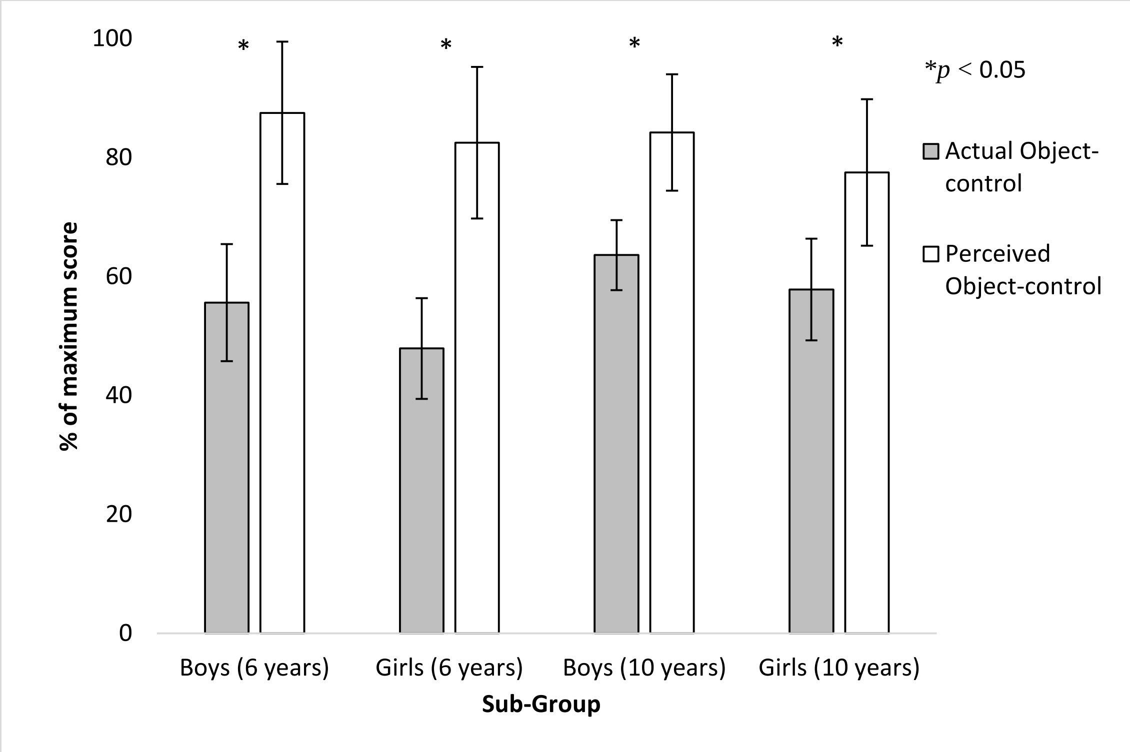

Figure 6.2: Perceived and actual object-control competence (± standard deviation)

For total FMS, the 6-year-old sub-groups had significantly greater PC-TOTAL than actual competence (p < 0.001, ES: 0.51 for both). Similarly, the 10-year-old sub-groups also had significantly higher PC-TOTAL than actual (10-year-olds boys: p = 0.019, ES: 0.15, 10-year-old girls: p = 0.001, ES: 0.24) indicating an overestimation of overall FMS competence (Figure 6.3).

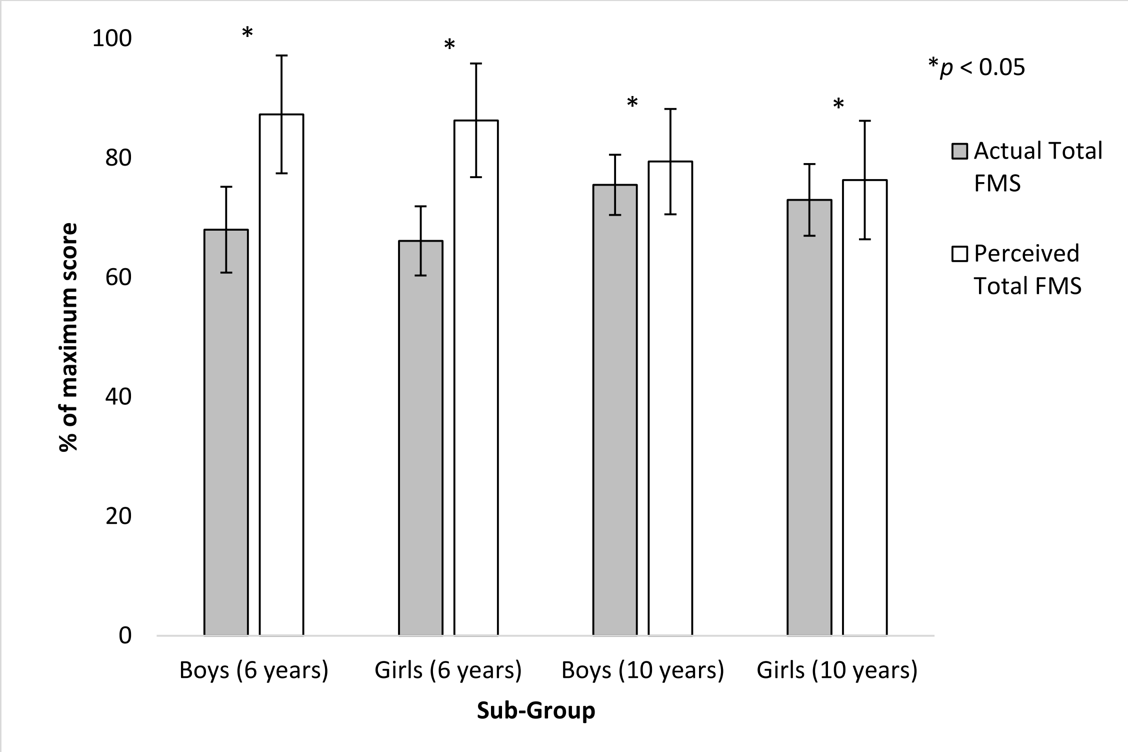

Figure 6.3: Perceived and actual total FMS competence (± standard deviation)

Tables 6.2 and 6.3 present the results of the hierarchical regression models for both actual FMS competence scores and MVPA as outcome variables, with measures of PC as independent variables (adjusting for age and sex). Results revealed that, while age (in favour of the older children) and sex (in favour of boys) were significant predictors ($p < 0.001$) for actual competence (locomotor, object-control and total FMS), accounting for almost 29% of the variance, corresponding PC scores were not (PC-LOCO: $p = 0.538$, PC-OC: $p = 0.743$, PC-TOTAL: $p = 0.574$, in their respective models). Similarly, the investigation of the relationship between PC-LOCO and MVPA also revealed that while age ($p = 0.047$) and sex ($p < 0.001$) were significant predictors in the model, PC-LOCO was not a significant predictor ($p = 0.07$) of time engaged in MVPA. In contrast, PC-OC ($p = 0.005$), as well as sex (in favour of boys) ($p < 0.001$) were significant predictors, accounting for 19.5% of the variance in MVPA. This model predicts that for each unit increase in PC-OC, there would be a 1.5minute increase in MVPA. Likewise, PC-TOTAL ($p = 0.006$), as well as age (in favour of older children)($p = 0.03$) and sex (in favour of boys)($p < 0.001$) were found to be significant predictors of MVPA, also accounting for 19.5% of the variance. In this model, for every unit increase in PC-TOTAL, there would be an increase of almost 1 minute (.942 minutes) of MVPA.

Table 6.2: Summary of hierarchical regression analyses for actual FMS subscales and Total FMS

		Beta (SE)	Standardized Beta	p-value	Adjusted R^2
Model 1	***Outcome: Actual LOCO****				
	Age	6.71 (0.68)	0.49	<0.001	0.29
	Sex	-2.06 (0.58)	-0.15	<0.001	
	PC-LOCO	-0.07 (0.11)	-0.03	0.538	
Model 2	***Outcome: Actual OC****				
	Age	6.90 (0.59)	0.51	<0.001	0.29
	Sex	-2.14 (0.60)	-0.16	<0.001	
	PC-OC	-0.03 (0.10)	-0.02	0.743	
Model 3	***Outcome: Actual TOTAL FMS****				
	Age	6.778 (0.64)	0.50	<0.001	0.29
	Sex	-2.13 (0.58)	-0.16	<0.001	
	PC-TOTAL	-0.04 (0.06)	-0.03	0.574	

NOTE: Age – 6 year olds coded as 0, 10 year olds as 1; Sex – Boys coded as 0, Girls as 1
*p < 0.001 for model

Table 6.3: Summary of hierarchical regression analyses for MVPA (min/day)

		Beta (SE)	Standardized Beta	p-value	Adjusted R^2
	Outcome: MVPA*				
Model 4	Age	7.41 (3.71)	0.17	0.047	0.17
	Sex	-17.32 (3.01)	-0.40	<0.001	
	PC-LOCO	1.06 (0.58)	0.15	0.070	
Model 5	Age	4.901 (3.10)	0.11	0.115	0.20
	Sex	-15.35 (3.09)	-0.35	<0.001	
	PC-OC	1.52 (0.54)	0.20	0.005	
Model 6	Age	7.57 (3.46)	0.17	0.030	0.20
	Sex	-16.46 (3.04)	-0.37	<0.001	
	PC-TOTAL	0.94 (0.34)	0.21	0.006	

NOTE: Age – 6 year olds coded as 0, 10 year olds as 1; Sex – Boys coded as 0, Girls as 1
*p < 0.001 for Model 4, 5 and 6

6.5 Discussion

An aim of this study was to investigate the relationship between perceived and actual skill competence among a cohort of 6-year-old and 10-year-old children. It was found that 6-year-olds (boys and girls) overestimated their overall FMS and object-control proficiency, indicating their inability to form accurate perceptions of their movement competence. In contrast, no significant difference was found between PC-LOCO and actual among both 6-year-old sub-groups suggesting that this cohort may be capable of forming accurate perceptions of their locomotor capabilities. However, the relatively high actual competence demonstrated by the 6-year-olds in the current study may have contributed to the accurate perceptions observed (Barnett et al., 2017). The overestimation of overall FMS and object-control proficiency is supported by other studies using the PMSC and TGMD-2, which report no association among 9 to 11-year-olds (Barnett et al., 2017), or only a weak positive association between perceived and actual object-control competence among 5 to 8-year-olds (Barnett, Ridgers, & Salmon, 2015; Liong et al., 2015). As suggested by previous research conducted on cognitive capacity, it is possible that this overestimation may result from children's limited cognitive capacity and inability to differentiate between effort, enjoyment and actual competency (Harter, 1999). The accurate perceptions of locomotor ability observed among the 6-year-old groups in the current study, contrasts the findings of Liong et al. (2015) and Barnett et al. (2017) who found no significant associations between perceived and actual locomotor competence in Australian children. These studies, were the only studies to assess the direct relationship between perceived and actual locomotor competence using the PMSC and TGMD-2. However, other studies using misaligned assessment instruments, have found a relationship between PC and actual competence in pre-school (LeGear et al., 2012; Robinson, 2011) and 6 to 7-year-old children (Toftegaard-Stoeckel et al., 2010), suggesting a weak-moderate positive association may exist in young children. Therefore, further investigation is warranted using aligned assessment tools to attain a more accurate understanding of this relationship.

In contrast, the 10-year-olds in this study underestimated their locomotor capabilities. However, similar to the 6-year-olds, object-control and overall FMS proficiency was overestimated. Our findings are supported by those of Barnett et al. (2017), the only other study to assess this relationship among children in middle childhood using the PMSC, who also found no association among 9 to 11-year-olds. As accuracy of children's perceptions is proposed to increase with age and cognitive development (Harter, 1999), it was not expected that the 10-year-old children would underestimate competency. As children cognitively develop, they begin to formulate perceptions based on past experiences, task difficulty, motivation and also reinforcement and interaction with significant others, including their peers (Harter 1978; Piaget 1959). It is possible that children may have felt they were 'good'/competent in performing a skill(s), but may have responded 'pretty good' as opposed to 'really good' due to the belief/awareness that others have superior ability (Barnett et al., 2017) and thus did not receive a score of 4 (indicating competency). The underestimation may also be due to children's reluctance to admit their true perceptions for fear of boasting or overestimating in the presence of the tester or the lack of understanding that 'really good' corresponds to the perception of competence in the skill.

Alternative approaches in using the PMSC, include administering a written/electronic version of the assessment, as well as explaining to older children the individual skill components required, which may help them select their competence level based on the scores/pictures with greater accuracy. The overestimation of object-control competence among 10-year-olds (and consequently overall FMS competence) may be due to their interpretation of the actual motor outcome, e.g. successful contact with the ball (which may not have occurred during the locomotor skills), as opposed to reflecting on the qualitative aspect of the movement (Barnett et al., 2017).

Among the current sample, regression analysis revealed there were no associations between any of the measures of PC (PC-LOCO, PC-OC or PC-TOTAL) and their respective measures of actual competence, after adjusting for age and sex. Previous studies, also using the PMSC and TGMD-2, have reported similar findings with no association found between PC-LOCO and actual locomotor competence (Barnett et al.,

2017) or between PC-OC and actual object-control competence (Barnett et al., 2017; Liong et al., 2015). These findings are in contrast to those reported by Barnett, Ridgers, and Salmon (2015) who found that perceptions of object-control competency did align with actual competence among 4- 8-year-old children. Likewise, LeGear et al. (2012) and Robinson (2011) also report significant association between perceived physical competence and actual competence. However, both of these studies did not use aligned measurement tools and were conducted among preschool children. The lack of association in this study between perceived and actual competence provides further evidence that children are unable to accurately perceive their skill competence.

There was also no significant association found between PC-LOCO and MVPA. Other studies carried out among children have reported similar findings, with no significant relationship observed between perceived FMS competence and MVPA among children, using both aligned (Barnett etal., 2017; Barnett, Ridgers, & Salmon, 2015; Slykerman et al., 2016) and unaligned (Lopes, Barnett, & Rodrigues, 2016) measures of PC and actual skill competence.

In contrast, PC-OC and PC-TOTAL were found to be significant predictors of MVPA in this study, after adjusting for age and sex. Similar findings are reported among preschool children, using an overall measure of perceived physical competence (LeGear et al., 2012; Robinson, 2011). These findings are supported by the systematic literature review by Babic et al. (2014), suggesting that higher self-perception is associated with higher PA levels in children, a relationship also proposed by the conceptual model of Stodden et al. (2008). The relationships identified are important as those with greater PC-OC will have greater motivation for sport and PA (Bagøien & Halvari, 2005), thus providing greater opportunities to develop actual competence, enabling continued PA participation. Therefore, interventions aimed at increasing children's PC (in particular object-control), as well as actual competence are warranted from an early age to help improve actual skill competence and also PA levels among children. It is possible that those with higher PA levels engage primarily in organised sport, most popular of which in Ireland include ball-related sports (i.e. Gaelic Football, hurling/camogie, soccer and rugby among boys) (Woods et al., 2010), thus encouraging the development of PC-OC and actual object-control competence. Future research examining the relationship between these measures and the sports children participate in may provide further insight into these relationships. Interestingly, previous research (Barnett, Ridgers, & Salmon, 2015; Barnett, Salmon et al., 2016; Liong et al., 2015; Slykerman et al., 2016) and findings in this study have reported that boys have been shown to exhibit greater perceived and actual object-control proficiency as well as higher PA levels than girls. With this in mind, particular emphasis to improve girls' perceived (and actual) object-control proficiency is needed to promote increased skill competence and PA levels among girls. While a strength of this study includes objectively measured PA, the sample assessed was significantly reduced due to limited accelerometer availability and therefore, further analysis of these relationships is warranted among a larger cohort of children. Also, PA data analysis was conducted across all weekdays (weekdays and weekend days inclusive). It is recommended that future research should also investigate the relationship between PC and PA across weekdays only and across weekend days only as this may provide further insight into these associations. Other limitations of this study include the relatively small sample size, with only three schools recruited for inclusion. While a small sample was involved in the current study, a wide range of the existing school types in Ireland participated, which included rural, urban, mixed sex, single sex girls and single sex boys schools. Further investigation using a greater sample size across a wider geographical area in Ireland may provide further support. Also, as this study is cross-sectional in design, a longitudinal study investigating these relationships over time may provide further support and insight into these associations.

6.6 Conclusion

The overestimation of competence by the 6-year-olds and 10-year-olds (object-control and overall FMS) has the potential to drive the acquisition of FMS, as those with higher PC have higher motivation, exert greater effort and attempt tasks to challenge their ability (Lopes, Barnett, & Rodrigues, 2016; Weiss & Amorose, 2005). This will lead to sustained (or possibly increases in) PC and PA levels. However, on the contrary, the underestimation of actual competence (locomotor skills among 10-year-olds) is worrying as low PC may negatively affect motivation (Bagøien & Halvari, 2005) and interest in PA. As PC has been found to track into adolescence (Barnett, Morgan et al., 2008), low PA levels may result. The positive association observed between PC-OC (and PC-TOTAL) and MVPA also highlights and indicates the importance of promoting PC among young children, especially girls, to increase actual competence and PA levels.

These findings highlight the need for the implementation of regular, well-designed movement skill programmes during the primary school years to promote the development of actual and perceived movement competence. It is imperative that such programmes include quality instruction, feedback as well as opportunities for practice (Gallahue & Ozmun, 2006). Evidence also suggests that the use of a mastery learning environment (in which children have the opportunity to individually improve and succeed) assists the promotion of actual and perceived FMS competence (Robinson, 2011; Theeboom, De Knop, & Weiss, 1995). As numerous health benefits are associated with actual and perceived movement competence, the successful implementation of such programmes during the early years may help combat the declining PA levels and rise in obesity evident worldwide.

The examination of children's FMS proficiency revealed that the FMS level of Irish primary school children is low (Chapter 5). Given such findings, two interventions were designed and delivered. The effectiveness of these interventions on children's FMS proficiency was evaluated. The methods used to carry out the interventions and their evaluations as well as the findings that were revealed from the evaluation of the two interventions are presented in the next chapter.

Chapter 7:

The effectiveness of two interventions on fundamental movement skill proficiency among a cohort of Irish primary school children

7.1 Abstract

Background: This study examined the effectiveness of a physical activity (PA) (Year 1) and a multicomponent fundamental movement skill (FMS) (Year 2) intervention on primary school children's FMS proficiency.

Methods: The interventions were delivered to all classes in two intervention schools, with a subset of classes selected for testing. Data were collected from 6- and 10-year-old cohorts from both intervention schools and age-matched groups from one control school, in south Ireland. In Year 1 (*N*=187), intervention (*n*=96) and control (*n*=91) groups were children from senior infant (6-year-old cohort) and fourth class (10-year-old cohort). In Year 2 (*N*=357), intervention (*n*=195) and control (*n*=162) groups were children from senior infant and first class (6-year-old cohort) and fourth and fifth classes (10-year-old cohort). FMS assessment was conducted across both academic years, using the Test of Gross Motor Development-2.

Results: Linear mixed models were used to investigate the effectiveness of each intervention, adjusting for age group.

Following Year 1, the intervention group significantly improved locomotor proficiency ($p<.05$), with no changes in object-control or overall proficiency. No group-time interactions were found. Following Year 2, the intervention group significantly improved locomotor, object-control and overall proficiency ($p<.001$). Group-time interaction effects were found for both subsets and overall FMS in favour of the intervention group ($p<.001$).

Conclusion: The FMS proficiency among primary school children were significantly greater following the multicomponent FMS intervention. Multicomponent FMS interventions, such as this, should be implemented across primary schools in Ireland to improve FMS proficiency among primary school children.

KEYWORDS: motor learning, pediatrics, motor development, early childhood; physical activity

7.2 Introduction

Children's ability to perform basic observable patterns of movement, known as fundamental movement skills (FMS) (Gallahue, Ozmun, & Goodway, 2012), is lower than desired (Bardid et al., 2016; Bolger et al., 2017; Khodaverdi & Bahram, 2015; Mitchell et al., 2013; Sepessato, Gabbard, Valentini, & Rudisill, 2013). Recent evidence and trends indicate lower FMS proficiency among children when compared to normative data collected 20 years ago (Bardid et al., 2016; Spessato et al., 2013). FMS (e.g. running, jumping, throwing) are considered the foundation or 'building blocks', upon which more complex sport-specific skills are based. The acquisition of these FMS facilitate and are beneficial for participation in physical activity (PA) and sport among childhood and adolescence (Gallahue et al., 2012; Logan, Robinson, Wilson, & Lucas, 2011). FMS are often categorised into locomotor skills, involving the movement of the body from one location to another (e.g. running, jumping) and object-control skills, involving the manipulation of an object (e.g. catching, kicking) (Lubans, Morgan, Cliff, Barnett, & Okely, 2010).

FMS proficiency are associated with numerous health benefits and are important for the physical, psychological, social, and overall well-being of children (Barnett et al., 2016). Proficiency in FMS has been shown to be positively associated with higher levels of moderate-vigorous physical activity (MVPA) (Holfelder & Schott, 2014), physical fitness (Barnett et al., 2016; Cattuzzo et al., 2016), cognitive functioning and academic performance (Haapala, 2013), and is inversely associated with a healthy weight status (Barnett et al., 2016; Lubans et al., 2010). Longitudinal evidence reveals that FMS proficiency tracks through childhood (Branta, Haubenstricker, & Seefeldt, 1984; Malina, 1990), into adolescence (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; McKenzie et al., 2002) and is a significant predictor of adolescent MVPA (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009). Worldwide, studies report large declines in MVPA with age, with decreases of as much as 55-64% observed in children from the age of five to 18 years old (Active Healthy Kids Australia, 2014; Kimm et al., 2002; Nader, Bradley, Houts, McRitchie, & O'Brien, 2008). However, those with higher FMS proficiency have been found to exhibit marginal decline in overall PA and so the development of FMS proficiency may not only be a mechanism to increase PA levels (including MVPA) and target obesity in childhood but may also prevent against age-related decline in overall PA (Barnett et al., 2009; Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2015; Lopes, Rodrigues, Maia, & Malina, 2011).

Although children have the potential to master FMS by the age of seven (Gallahue et al., 2012), FMS are not acquired naturally (Barnett et al., 2016; Clark, 2005). Rather, it is through quality practice of the skill, as well as quality instructional provision during learning that these skills are developed and mastered (Gallahue et al., 2012; Payne & Isaacs, 2002). Therefore, the early years (3-7 years old) are a critical period in the development of FMS (Gallahue et al., 2012). During this developmental period in Ireland, children (4-13 years old) spend approximately 4.5-5.5 hours (class and school dependent) in primary school throughout the academic year (a minimum of 40% of their waking day) (Department of Education and Skills, 2017). The primary school setting offers an ideal opportunity for the development of FMS. In addition, primary schools in Ireland boast the necessary resources, facilities, possible opportunity within the Physical Education curriculum and access to all attending children (including those who are at risk of developmental delays, being inactive and/or overweight/obese) to facilitate FMS development (Lander, Eather, Morgan, Salmon, & Barnett, 2017; Wiart & Darrah, 2001).

In a systematic review of the effectiveness of PA interventions (school-based) on PA and physical fitness in children and adolescents (Kriemler et al., 2011), few studies were included which evaluated the effectiveness of such interventions on what is referred to as 'motor skill' competence (i.e. FMS or motor tasks). Mixed findings were reported with four of the six included studies showing significant intervention effects on some of the motor skills/tasks assessed (Kriemler et al., 2011). Currently, there is a dearth of research investigating the effectiveness of PA interventions which do not have a specific FMS focus, on fundamental movement skill proficiency.

School-based motor skill interventions, however, have been reported to positively improve FMS proficiency among primary school aged children (Morgan et al., 2013). One such intervention which has been successfully implemented for over 10 years is

Project Energize, a health promotion intervention programme delivered across primary schools in New Zealand (Rush et al., 2016). Since its first implementation in 2005/2006 across 124 primary schools, it has since developed and is currently implemented in all 242 primary schools in the Waikato area as well as 70 schools from other areas, reaching 53,000 children (Rush et al., 2016). Project Energize has been shown to be a sustainable project, effective in increasing FMS, reducing obesity and increasing physical fitness among school children, while remaining cost effective and efficient (Rush et al., 2016). Central to Project Energize is a qualified specialist (i.e. teachers or graduates in the field of exercise and nutrition) known as an 'Energizer'. The qualified specialist implemented the intervention and acted as 'agents of change' in their designated school(s), as opposed to additional members of staff. The roles and responsibilities of the qualified specialist included conducting a needs analysis with school staff and teachers as well as providing and discussing models and plans for physical education and fitness classes. Useful information and resources (including FMS manuals) were also provided to teachers (Mitchell et al., 2013). Following the Project Energize intervention among 5- to 12-year-olds in New Zealand, significant FMS improvements were observed in all 10 FMS assessed using the Test of Gross Motor Development (kick, throw, strike, skip, jump, leap, gallop, bounce, catch, hop, slide, and run) (Mitchell et al., 2013). Individual skill improvements ranged from 13.7% (in the run) to 36.3% (in the strike).

Motor skill interventions most consistently associated with improvements in FMS have been identified as those including a multi-disciplinary approach, of long duration (> 6 months), providing multiple sessions per week, delivered by a physical education specialist and those incorporating parental involvement (e.g. 'at home' practice assisted or supervised by parents, parent evenings) (Tompsett, Sanders, Taylor, & Cobley, 2017). A large effect size for overall (*standardised mean error* = 1.42) and locomotor (*standardised mean error* = 1.42) proficiency have been reported following such interventions, with a medium effect size (*standardised mean error* = .63) reported for object-control proficiency (Morgan et al., 2013). It is suggested that greater instruction and practice are needed for object-control skills than locomotor skills due to the greater perceptual demand and complexity of the object-control skill components, accounting for the disparity in intervention effects (Morgan et al., 2013).

A recent assessment of FMS proficiency among a cohort of Irish primary school children (*n*=203) revealed that FMS levels are less than satisfactory, with children demonstrating significantly poorer FMS proficiency levels compared with US normative data (*n*=1208) (Bolger et al., 2017). Furthermore, a study conducted by O'Brien, Belton and Issartel (2016) highlighted that Irish primary school children enter adolescence with low FMS proficiency. Based on the theorised reciprocal relationship between FMS and PA (Stodden et al., 2008), it is not surprising, therefore, that childhood physical inactivity is a major problem and concern in Ireland (Kelly, Gavin, Molcho, & Nic Gabhainn, 2012; Morgan et al., 2008). International comparisons reveal that Irish children have low PA levels as well as high levels of sedentary behaviour (Tremblay, 2014), with only 19% of primary school aged children reaching the recommended 60 minutes of MVPA daily (Woods, Moyna, Quinlan, Tannehill, & Walsh, 2010). Also, despite the recommended time allocation of 60 minutes for Physical Education per week (accounting for a mere 4% of curriculum time), it has been found that Irish primary school children only received 46 minutes of Physical Education time per week (European Commission/EACEA/Eurydice, 2013), which was found to be lower than all other EU countries. Furthermore, according to a World Health Organization study involving 53 European countries, Ireland has been predicted to be the fattest of these nations by 2030 (Webber et al., 2014).

Given the current levels of FMS and PA among Irish children, the implementation of an effective intervention is warranted. Such an intervention may provide children with the necessary skills to facilitate PA and sport participation across the lifespan. Therefore, the aims of the study were to examine the effectiveness of: (i) a PA intervention (without an FMS focus) and, (ii) a multicomponent FMS-based intervention (each delivered across one academic year) on the locomotor, object-control, overall FMS proficiency, and FMS mastery levels of a cohort of Irish primary school children.

7.3 Methods

Participants

Data collection was conducted as part of *Project Spraoi*, a primary school-based PA and nutrition intervention project (Coppinger, Lacey, O'Neill, & Burns, 2016) based on Project Energize, New Zealand (Rush et al., 2016). The 'Project Energize' intervention was tailored for implementation in an Irish setting, accounting for cultural, environmental and curriculum differences (including most popular sports, weather, facilities, open space and time available for Physical Education and PA within the school curriculum) between the countries (Coppinger et al., 2016). Three primary schools including two urban single-sex intervention schools (one boys and one girls) and one rural mixed control school from a region in southern Ireland were invited to participate. The interventions were delivered to all children in both intervention schools, with a subset of classes selected for testing. To align with Project Energize, two cohorts of similar age (6-year-old and 10-year-old) were selected for testing. Testing age-groups, similar to those assessed by Project Energize were selected (6-year-old and 10-year-old cohorts), as these age groups have been highlighted as important developmental periods during childhood. The 6-year-old cohort was selected, as this will allow the evaluation of the effectiveness of the interventions among children as they experience the 'mid-childhood rise in BMI (known as 'adiposity rebound'), which has been identified as a critical period for later morbidity and mortality in adulthood (Graham et al., 2008). The 10-year-old cohort was selected as this will allow the evaluation of the effectiveness of the interventions among children as they transition into puberty (Graham et al., 2008). Ethical approval was obtained from Cork Institute of Technology Research Ethics Review Committee.

Intervention 1: PA Intervention

From a total of 301 eligible children from senior infants (~6-year-olds) and 4th classes (~10-year-olds), written informed parental consent for involvement in the study was obtained for 203 children (67% consent rate). Data were collected at both baseline (October 2014) and follow-up (June 2015) from 187 children (92% retention rate), including 96 children from the intervention schools (51 boys, 45 girls) and 91 children from the control school (52 boys, 39 girls). Missing data are accounted for by absences and school events (see Table 7.1).

Intervention 2: Multicomponent FMS Intervention

From a total of 595 eligible children from senior infants (~6-year-olds), 1st (~7-year-olds), 4th (~10-year-olds) and 5th (~11-year-olds) classes, written informed parental consent for involvement in the study was obtained for 448 children (75% consent rate). Data were collected at both baseline (October 2015) and follow-up (June 2016) from 357 children (80% retention rate). This included 195 children from the intervention schools (92 boys, 103 girls), all of whom had received the PA intervention during the previous academic year and 162 children from the control school (92 boys, 70 girls), 75 (46%) of whom were also in the control group for the PA intervention. Missing data are accounted for by absences, school events and injuries (see Table 7.1).

Anthropometric Measures

Anthropometric data were collected prior to FMS assessment. Height was measured to an accuracy of .1cm using a Leicester portable height scales. Body mass was measured to an accuracy of .1kg, using a Tanita WB100MZ portable electronic scale. Shoes were removed for both measures. Body Mass Index (BMI) was calculated as weight (kg) divided by height (m^2). Children were classified into BMI categories (i.e. normal, overweight/obese) using age and sex-specific cut-off points developed by Cole, Bellizzi, Flegal, and Dietz (2000).

FMS Assessment

FMS proficiency was measured using the Test of Gross Motor Development-Second Edition (TGMD-2) (Ulrich, 2000). This FMS assessment instrument, which has been used globally to assess FMS proficiency among children (Bakhtiar, 2014; Bolger et al., 2017; Burrows, Kolen, & Keats, 2014; Cliff, Okely, Smith, & McKeen, 2009; Hardy, King, Farrell, Macniven, & Howlett,, 2010; Spessato et al., 2013), is a criterion and norm-referenced, process-oriented tool that has been found to be both valid and reliable for use among children aged 3-10 years (Ulrich, 2000). The TGMD-2 consists of two subsets of skills; locomotor and object-control. The six locomotor skills assessed are the run, gallop, slide, leap, hop and horizontal jump. The six object-control skills assessed are the kick, catch, overhand throw, strike, underhand roll, and dribble.

FMS Data Collection

Data were collected at four time points: September 2014 (pre-intervention 1), June 2015 (post-intervention 1), September 2015 (pre-intervention 2), and June 2016 (post-intervention 2). Testing was conducted by a cohort of nine trained evaluators from the *Project Spraoi* Research Team (postgraduate researchers and staff of Cork Institute of Technology and University College Cork). Prior to testing, evaluators completed an FMS-testing training workshop which was delivered by a research practitioner with extensive experience using the TGMD-2. Testing of each class group replicated the protocol used and described by Bolger et al. (2017).

FMS Scoring Protocol

The videos of the test trials were uploaded to a laptop, and analysed retrospectively. Each FMS consists of 3-5 behavioural components. If a component was performed correctly, a score of 1 was awarded. If the behavioural component was performed incorrectly, a score of 0 was awarded. This procedure was carried out for each of the two test trials, and scores from both trials were then summed to obtain a raw skill score (Ulrich, 2000). 'Mastery' of an FMS was achieved, when all components of a skill were present (i.e. skill performed correctly) across both test trials.

Locomotor and object-control subset scores were calculated by summing the raw scores of the individual skills within each subset (Locomotor Score Range: 0-48; Object-Control Score Range: 0-48). Subsequently, locomotor and object-control standard scores were derived, based on age and sex, using the conversion tables outlined in the TGMD-2 (Ulrich, 2000). Locomotor and object-control standard scores were summed, and then converted to a Gross Motor Quotient (GMQ), based on age and sex. GMQ was then used to categorise the locomotor, object-control and overall FMS performance of each child into one of seven categories, ranging from *very poor* to *very superior*. Children with a standard score (locomotor/object-control) between 1-3 were classified as *very poor*, between 4-5 classified as *poor*, 6-7 as *below average*, 8-12 as *average*, 13-14 as *above* *average*, 15-16 as *superior* and 17-20 as *very superior* in terms of locomotor/object-control proficiency (Ulrich, 2000). Subtest standard scores and classification categories allow comparisons to be made across the subtests (locomotor and object-control), which aid the identification of strengths/weaknesses in the respective subtests. A similar scoring protocol was used to classify the overall FMS proficiency of children using the GMQ (*very poor*: <70; *poor*: 70-79; *below average*: 80-89; *average*: 90-110; *above average*: 111-120; *superior*: 121-130; *very superior*: >130) (Ulrich, 2000). GMQ scores and classification categories, reflect the overall gross motor development (combined locomotor and object-control proficiency) of an individual. Both standard scores and GMQ may be used to guide the development of appropriate motor development programmes.

Inter-rater and intra-rater reliability was established between a research practitioner with extensive experience using the TGMD-2, and the two principal researchers conducting the video analysis. Inter- and intra-observer agreements were calculated for 10% of the sample, using the equation (agreements/ (agreements + disagreements)) x 100 (Thomas, Nelson, & Silverman, 2011). The inter- and intra-reliability scores across the 12 FMS ranged from 86-99% agreement, all of which are accepted standards and greater than the recommended 85% threshold required to demonstrate reliability (Thomas et al., 2011).

Table 7.1: Descriptive statistics and mean pre- and post-intervention subset scores (SD), for both interventions

Variable	Year 1				Year 2			
	Intervention (*n*=96)		Control (*n*=91)		Intervention (*n*=195)		Control (*n*=162)	
	6-year-olds (*n*=45)	10-year-olds (*n*=51)	6-year-olds (*n*=50)	10-year-olds (*n*=41)	6-year-olds (*n*=92)	10-year-olds (*n*=103)	6-year-olds (*n*=77)	10-year-olds (*n*=85)
Age (years)	5.9 (.4)	9.9 (.4)	6.1 (.3)	10.0 (.4)	6.3 (.6)	10.4 (.6)	6.6 (.6)	10.5 (.5)
Height (cm)	114.8 (6.0)	140.4 (6.6)	116.4 (4.4)	140.5 (5.3)	117.9 (6.8)	142.7 (7.2)	119.6 (5.9)	143.2 (5.5)
Mass (kg)	21.4 (3.2)	36.0 (7.7)	21.3 (2.7)	34.7 (5.8)	23.2 (4.2)	37.6 (8.8)	23.1 (3.2)	37.1 (6.3)
Body Mass Index (BMI)	16.2 (1.8)	18.2 (2.9)	15.7 (1.3)	17.5 (2.3)	16.6 (2.1)	18.3 (3.1)	16.1 (1.4)	18.0 (2.3)
Pre Locomotor Score (range: 0-48)	38 (4)	42 (4)	40 (3)	41.7 (3)	39 (4)	42 (4)	40 (3)	42 (3)
Post Locomotor Score (range: 0-48)	41 (3)	43 (3)	42 (3)	42.5 (3)	43 (3)	46 (3)	39 (4)	41 (3)
Pre Object-control Score (range: 0-48)	28 (6)	39 (4)	30 (5)	39.8 (3)	31 (5)	38 (4)	34 (5)	40 (4)
Post Object-control Score (range: 0-48)	30 (6)	39 (4)	32 (5)	39.9 (3)	36 (4)	43 (3)	31 (5)	38 (4)
Pre TOTAL FMS Score (range: 0-96)	66 (8)	81 (6)	70 (5)	81.5 (4)	71 (7)	80 (6)	73 (7)	82 (5)
Post TOTAL FMS Score (range: 0-96)	71 (7)	82 (5)	74 (6)	82.4 (4)	79 (6)	88 (4)	70 (7)	80 (5)

FMS: fundamental movement skills

Interventions

Intervention 1

The PA intervention was designed and developed based on Project Energize, New Zealand (Rush et al., 2016). Following a needs analysis conducted with the principal and teachers in each school, the intervention was adapted and tailored to the specific needs of the school. The intervention was delivered by the qualified specialist (known as the Energizer) across 26 weeks (the academic year 2014-2015, excluding school holidays) in two single-sex primary schools (one girls and one boys). Each week, two 25-minute *huff and puff* lessons (i.e. games/activities facilitating MVPA) were delivered in accordance with the Irish Physical Education curriculum strands of Athletics, Dance, Games, Outdoor Adventure and Gymnastics. Sessions delivered by the qualified specialist replaced the allotted Physical Education class time in the girls' school, while the boys' school also received a 30-minute weekly Physical Education class delivered by the classroom teacher. This difference was due to individual school preferences. The role of the qualified specialist was multi-faceted, including developing and designing *huff and puff* lesson plans and associated resources, modelling PA lessons, as well as providing on-going support to classroom teachers throughout the intervention. While the intervention was delivered to the children, it was also aimed to be both educational and empowering for teachers. To empower teachers, the Energizer-led sessions were designed not only as lessons in which the children were learning but also as model lessons for the teachers who were encouraged to repeat and/or adapt for use on the days that the qualified specialist was not in the school. During these sessions teachers were invited to assist the qualified specialist in the delivery of the lesson. Teacher professional development was also provided through a practical training workshop. This workshop aimed to increase PA knowledge and covered the following aspects: (i) the importance of MVPA (ii) developmentally age-appropriate *huff and puff* activities and (iii) classroom PA activities. Classroom teachers also received PA and classroom activity manuals, developed by the qualified specialist. Various PA initiatives and sports days were also organised throughout the academic year to promote PA in the school and home environment (see Table 7.2). Classroom teachers were encouraged to deliver a minimum of 20 minutes of MVPA on school days during which children did not receive a specialist-led session (i.e. three school days per week). Activities incorporating MVPA which could be used to facilitate additional PA, were modelled during sessions delivered by the qualified specialist, demonstrated during the practical training workshop and also included in the various resource manuals distributed to each classroom teacher. The control school did not receive any intervention material or support (i.e. classroom teachers delivered the Irish Physical Education curriculum only, which was delivered during a weekly 1-hour Physical Education class).

Intervention 2

The multicomponent FMS intervention, was developed using elements from Project Energize (Mitchell et al., 2013; Rush et al., 2016), the Y-PATH school-based FMS and PA intervention for Irish adolescents (Belton, O'Brien, Meegan, Woods, & Issartel, 2014) and previous motor skill interventions (Logan et al., 2011; Morgan et al., 2013). It was delivered by the qualified specialist (who had delivered the Year 1 intervention) across the academic year 2015-2016 (excluding school holidays) in the two single-sex schools. The FMS intervention consisted of numerous FMS-specific components, of which are described in Table 7.2. Across the 26-week intervention, each individual FMS was the focus for a two-week block, the order of which was determined by each school, to reflect the skills applicable within the Physical Education strand being delivered at the time. For example, the run was one of the skills focussed on during the period in which the Athletics strand was usually delivered. A two-week recap period (consisting of four lessons) was also provided prior to the culmination of the intervention. Each of these recap lessons incorporated the revision of four FMS and engagement in age-appropriate activities involving the practice of these skills.

Table 7.2: Detailed description of the multicomponent fundamental movement skills (FMS) intervention

Component	Description
1. FMS-based Lesson plans	FMS-based lesson plans were developed and delivered in line with the Irish PE curriculum. These included (i) a warm up (incorporating a FMS previously learned), (ii) skill development and (iii) a moderate-vigorous intensity game, incorporating the skill. Variations and progressions were included.
2. Energizer-led Lessons	The Energizer delivered two x 25-minute weekly sessions which demonstrated FMS and PA activities which classroom teachers were encouraged to repeat during the week to help improve FMS and accumulate a target of 20 minutes of MVPA daily. This could be achieved in one activity session or with numerous activity breaks throughout the school day. Cross-curricular and classroom activities were also modelled and resources provided to the teacher. School FMS and PA initiatives and competitions were organised throughout the year.
3. FMS Posters	A series of FMS posters were designed for each skill and hung on the walls in each classroom during the two-week period in which the said skill was the main focus during lessons. Posters depicted the correct technique as well as relevant teaching cues (as used in the lessons) for the given skill.
4. FMS Homework Manual	FMS homework manuals contained images depicting the correct technique and cues for each FMS and age-appropriate activities catering for varying skill levels. Many activities could be performed with a partner(s), encouraging parent involvement. FMS homework, distributed by the classroom teacher, reflected the FMS in focus during that period. Children/parents recorded the activities completed and the level of difficulty experienced in performing the skill/activities, in the manual to achieve 'homework points'. Prizes (e.g. ball, tennis racket) were distributed to the children based on homework points earned at term-end.
5. Professional Development	Teachers participated in an FMS practical workshop delivered by the Energizer. This workshop aimed to increase FMS knowledge and covered the following aspects: (i) developmentally age-appropriate cues and demonstration of correct FMS technique, (ii) identification and correction of common errors relevant to each FMS and (iii) developmentally age-appropriate FMS activities incorporating each of the FMS. Teachers received an FMS manual which included (i) a detailed description of how to perform each skill correctly, (ii) images depicting correct technique and cue words relevant to each FMS, (iii) common errors observed for each FMS, (iv) useful tips for teaching each skill and (v) skill-specific activities and variations, to allow differentiation for a broad age and skill range. In addition, teachers were provided with a classroom activity resource, which contained cross-curricular FMS activities and high-intensity dance routines (incorporating FMS), suitable for restricted space. Outdoor activity resources were also provided.
6. FMS Activity Breaks	FMS and PA Classroom Break Charts were introduced to aid teachers in the attempt to facilitate 20 minutes FMS practice (and PA) during the school days on which the Energizer was not present. These charts were designed to encourage short activity breaks (six per day) involving two activities; one *huff and puff* activity (such as high knees) and also the practice of an FMS (e.g. 10 ball catches with a partner), which varied daily. Each time the activities were completed, a tick was recorded on the chart, representing a score of 1 point. Any additional FMS practice or PA time was also recorded, with each minute corresponding to 1 point. Each week, total FMS practice and PA

	accumulated was calculated for each class and recorded on the school leaderboard in the sportshall. At term-end, small prizes (e.g. certificates (Appendix D.6), homework passes (Appendix D.7)) were distributed to the class and teacher with the highest points.
7. Other PA Initiatives	**Stride for 5:** The aim was for each class group to run continuously for five minutes. Children attempted to run continuously for one minute with the Energizer present. If successful, without any student stopping or walking, the class progressed and could attempt two minutes the following week. If any student stopped or walked during an attempt, the class could not progress to the next level. The progress of each class was recorded on the 'Stride for 5' ladder in the sportshall. When a class achieved five minutes running, their class name was placed above the ladder highlighting their achievement.
	Kilometre Challenge: The aim was to complete the 1km (e.g. 5 x 200m loop marked on yard) as fast as possible. Children received their run time after each attempt on an individual score card. Each time they attempted the 1km challenge, children attempted to improve their own individual time. Prizes (e.g. rulers, pens) were awarded to children for effort and improvements made and to teachers for attempts made to facilitate the practice of the 1km run. At the end of the challenge (five weeks), each child received a final score card showing their initial and final run times.
	Paper Rush: Children ran around a marked loop (approx. 40m) in the school yard/hall for a set time e.g. 1min/2min/3min. At opposite sides of the loop were two boxes; one empty and one filled with paper balls. Children raced around the route, attempting to move as many paper balls as possible from the full box to the empty box. Only one ball could be moved per student each loop/lap. At the end of the time, the balls were counted and the score recorded on the Paper Rush scoreboard in the PE hall.
	PE Student of the Week: At week-end, the classroom teacher awarded a 'PE Student of the Week', chosen based on effort made to improve their FMS, enthusiasm and willingness to learn during PE and PA sessions. The PE Student of the Week received a certificate which was placed on a large PE Student of the Week poster hung outside each classroom door and brought home the following week.
	Active Agent: The 'Active Agent' was the title given to the PE Student of the Week from the previous week. They had numerous roles including marking the PA Break Charts, moving the class marker on the Stride for 5 poster, reminding and encouraging the teacher to take classroom and outdoor PA breaks, reminding the teacher about FMS homework and also had responsibilities during lessons including assisting with and/or giving demonstrations and collecting and returning equipment.

FMS: fundamental movement skills, PA: physical activity, PE: Physical Education

Data Analysis

Statistical analysis for Intervention 1 and Intervention 2 were carried out using SPSS version 22.0. Only participants with complete data sets at baseline and post-intervention testing were included in the analyses. Descriptive statistics were calculated by treatment group (i.e. intervention/control) and age group (6-year-olds/10-year-olds) to describe baseline and post-intervention age, height, mass, BMI, locomotor and object-control subset scores and total FMS scores.

At baseline of Intervention 1 and Intervention 2 equivalence testing was used to assess group similarities (intervention/control) in locomotor standard score, object-control standard score, and GMQ score. The equivalence margin was selected based on the difference in standard scores and GMQ between treatment groups at baseline reported by previous research (Johnstone, Hughes, Janssen, & Reilly, 2017), as suggested by Walker and Nowacki (2011). Intervention effects on subset standard scores and GMQ were investigated using linear mixed models, with treatment group (intervention or control), time (pre- or post-intervention) and group-time interaction forming the base of the model and age/class groups (senior infants/1st class or 4th/5th class) as a random effect. Intraclass correlation was calculated to compare the variation between age/class groups as a fraction of the total variance.

As categories are often used in the reporting of TGMD-2 scores, descriptive statistics are reported for the number of children in each category pre- and post-intervention 2. Cochrane's Q tests were also used to investigate if there was a statistically significant difference in the proportion of children achieving mastery in the 12 individual FMS from pre to post-intervention, within each treatment group. The alpha level required for significance for all tests was set at $p < .05$.

7.4 Results

Intervention 1

Table 7.3 presents the mean locomotor standard score, object-control standard score, and GMQ, accounting for age and sex, at pre- and post-intervention 1, with respect to treatment group. At baseline, equivalence was found between the intervention and control group for locomotor standard score (p < .001), object-control standard score (p < .001), and GMQ (p < .01).

Results from the linear mixed models are displayed in Table 7.3. It was found that the intervention group significantly improved locomotor standard score (p = .041). However, there were no significant changes in object-control standard score or GMQ among the intervention group. Similarly, among the control group, there were no significant changes in locomotor standard score, object-control standard score, or GMQ. No group-time interactions (i.e. significant differences between groups over time) were found for locomotor standard score, object-control standard score, or GMQ, p > .05 for all.

Intervention 2

Mean locomotor standard score, object-control standard score, and GMQ, accounting for age and sex, for both intervention and control group at pre- and post-intervention 2 are presented in Table 7.3.

At pre-intervention 2, equivalence was found between the intervention and control group for locomotor standard score (p < .001), object-control standard score (p < .001), and GMQ (p < .01). Results from the linear mixed models (Table 7.3), found that the intervention group significantly improved locomotor standard score, object-control standard score, and GMQ from pre- to post-intervention. In contrast, the control group significantly dis-improved in locomotor standard score, object-control standard score, and GMQ from pre- to post-testing. A group-time interaction effect was found in favour of the intervention group for locomotor standard score, object-control standard score, and GMQ.

Table 7.3: Changes in mean (SD) Locomotor Standard Score, Object-control Standard Score, and Gross Motor Quotient (GMQ)

Score	Baseline	Post-test	*p*-value[a]	Baseline	Post-test	*p*-value[a]	Adjusted Difference in Change (95% CI)[b]	p-value[c]	ICC[d]
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)				
Intervention 1	**Intervention (*n*=96)**			**Control (*n*=91)**					
Locomotor Standard Score	9.9 (2.5)	10.4 (2.0)	.041	10.2 (2.4)	10.5 (2.3)	.291	-.23 (-.5 to .4)	.498	.34
Object-control Standard Score	8.0 (2.0)	7.9 (2.2)	.362	8.4 (1.7)	8.3 (1.9)	.716	-.30 (-.8 to .2)	.708	.09
GMQ	93.9 (10.7)	94.8 (9.7)	.364	95.8 (9.6)	96.3 (9.9)	.594	-1.0 (-3.2 to 1.2)	.801	.33
Intervention 2	**Intervention (*n*=195)**			**Control (*n*=162)**					
Locomotor Standard Score	9.9 (2.2)	11.7 (2.1)	<.001	9.8 (2.0)	8.8 (1.9)	<.001	1.5 (1.2 to 1.9)	<.001	.08
Object-control Standard Score	8.2 (2.2)	9.8 (2.3)	<.001	8.4 (2.2)	6.9 (1.9)	<.001	1.3 (.9 to 1.7)	<.001	.05
GMQ	94.4 (11.0)	104.5 (10.5)	<.001	94.5 (10.7)	87.1 (9.3)	<.001	8.5 (6.8 to 10.3)	<.001	.08

GMQ: Gross Motor Quotient
a: Within-group change over time.
b: Adjusted mean difference and 95% CI between each respective intervention and control group (intervention minus control); results from linear mixed model with random effect for age group.
c: Group–time interaction from mixed model that included baseline and post-test data and covariates.
d: ICC for age group.

Prevalence of Mastery Levels

The proportion of children achieving mastery (percentage mastery) at pre- and post-intervention 2 in each of the 12 FMS, by group and age, are presented in Table 7.4. The percentage mastery in the 6-year-old intervention group, significantly increased in eight skills (run, hop, slide, jump, throw, roll, kick, and dribble), and decreased in the gallop ($p < .05$). Increases in percentage mastery among this group, in the leap, catch, and strike were not significant. Among the control group there was a significant increase in the percentage mastery in the slide while there were significant decreases in the gallop and the throw ($p < .05$). There were no significant differences in the percentage mastery in the other nine skills for the control group.

In the 10-year-old intervention group, there were significant increases in the percentage of children who achieved mastery in seven skills (hop, slide, jump, throw, roll, kick, and dribble), while there was a significant decrease in the catch ($p < .05$). Increases in percentage mastery in the run, leap, and strike were not significant for children in the intervention group. Among 10-year-old children in the control group, there were significant increases in the percentage mastery in three skills (leap, kick, and dribble) and significant decreases in three skills (gallop, catch, and roll). There were no significant differences in the percentage mastery in the other six skills.

Table 7.4: Intervention 2: Percentage of children achieving mastery pre- and post-intervention in the 12 fundamental movement skills (FMS) of the Test of Gross Motor Development-2 (TGMD-2)

6-year-olds									**10-year-olds**								
Skill	**Intervention**				**Control**				**Skill**	**Intervention**				**Control**			
	Pre (%)	**Post (%)**	***Q***	***p*-value**	**Pre (%)**	**Post (%)**	***Q***	***p*-value**		**Pre (%)**	**Post (%)**	***Q***	***p*-value**	**Pre (%)**	**Post (%)**	***Q***	***p*-value**
Run	75.0	87.0	4.17	.041	79.2	76.6	.15	.695	**Run**	84.5	88.3	.80	.371	91.8	85.9	1.47	.225
Leap	69.6	70.7	.03	.869	71.4	61.0	2.29	.131	**Leap**	69.9	79.6	2.94	.086	57.6	76.5	7.53	.006
Hop	16.3	38.0	13.33	<.001	22.1	18.2	1.00	.317	**Hop**	51.5	66.0	5.77	.016	55.3	50.6	.62	.433
Gallop	73.9	45.7	16.90	<.001	77.9	22.1	39.34	<.001	**Gallop**	80.6	85.4	.86	.353	84.7	55.3	20.16	<.001
Slide	48.9	83.7	24.38	<.001	19.5	44.2	10.94	.001	**Slide**	60.2	89.3	20.46	<.001	51.8	43.5	1.69	.194
Jump	1.1	34.8	31.00	<.001	.0	2.6	2.00	.157	**Jump**	2.9	50.5	49.00	<.001	3.5	.4	.33	.564
Catch	20.7	23.9	.29	.590	23.4	13.0	3.56	.059	**Catch**	72.8	59.2	4.67	.031	84.7	40.0	32.82	<.001
Throw	8.7	25.0	9.00	.003	26.0	9.1	7.35	.007	**Throw**	25.2	45.6	10.76	.001	21.2	28.2	1.29	.257
Roll	2.2	14.1	9.31	.002	5.2	1.3	1.80	.180	**Roll**	8.7	55.3	44.31	<.001	22.4	8.2	7.20	.007
Strike	14.1	23.9	3.00	.083	18.2	10.4	2.57	.109	**Strike**	21.4	25.2	.44	.505	23.5	18.8	1.14	.285
Kick	35.9	57.6	11.77	.001	45.5	50.6	.80	.371	**Kick**	68.0	82.5	8.33	.004	83.5	94.1	5.40	.020
Dribble	4.3	20.7	11.84	.001	5.2	5.2	.00	1.000	**Dribble**	42.7	81.6	32.00	<.001	37.6	52.9	4.57	.033

Q = Cochrane's Q

TGMD-2 Categories

LOCOMOTOR Standard Score

The proportion of children from the intervention and control groups in each of the seven TGMD-2 (ranging from *very poor* to *very superior*) categories for locomotor standard score, at pre and at post-intervention 2 are shown in Table 7.5. While 50% of children in the intervention group remained in the same category following the intervention, 34% of children improved by one category, 8% by 2 categories, and 2% by 3 categories. In contrast, 69% of the control group remained in the same category, 7% improved one category, while the remaining 25% dis-improved into a category at least one level below. At baseline and follow up, no child in either the intervention or control group, was categorised as *very poor*. In the intervention group, there were decreases in the proportion of children in the *poor* (4% to 1%), *below average* (8% to 1%), and *average* (79% to 55%) categories following the intervention, while increases were observed in the proportion of children in the *above average* (7% to 37%), *superior* (3% to 6%) and *very superior* (0% to 1%) categories. In contrast, in the control group, the proportion of children in the *average, above average and superior* group decreased from baseline to post-intervention, while increases in those in the *poor and below average* categories were evident (see Table 7.5).

OBJECT CONTROL Standard Score

The proportion of children from the intervention and control groups in each of the seven TGMD-2 categories for object-control standard score, at pre- and post-intervention 2, are shown in Table 7.5. At post-intervention 2, while 49% of children in the intervention group remained in the same category, 31% of children improved by one category, 8% by 2 categories, and 3% by three categories. Although a similar proportion of children in the control group remained in the same category (46%) as the intervention group, 46% of children dis-improved into a category at least one level lower than pre-intervention 2, while only 8% improved into a higher category. At both pre- and post-intervention 2, there were no children from either intervention or control group, in the *superior* or *very superior* category. In the intervention group, there was no longer any child in the *very poor* category following the intervention. There were also decreases in the proportion of children in the *poor* (from 11% to 2%) and *below average* (29% to 16%) categories, which resulted in increases in the proportion of children classified as *average* (from 58% to 69%), *above average* (from 2% to 11%), and *superior* (from 0% to 2%). In the control group, the proportion of children in the *very poor, poor,* and *below average* categories increased resulting in decreases in the proportion of children in the *average* and *superior* categories.

Gross Motor Quotient (GMQ)

Data relating to the TGMD-2 categories for GMQ at baseline and follow up are presented in Table 7.5. Following the intervention, while 47% of children in the intervention group remained in the same category as pre-intervention 2, 30% of children improved into a GMQ category one level higher than pre-intervention 2, while 14% improved by two categories, and a further 3% improved by three categories. In contrast, despite 46% of the control group remaining in the same category as pre-intervention 2, 47% dis-improved into a category at least one level lower, with only 7% improving into a higher category. In the intervention group, following the intervention, there were no longer any children classified in the *very poor* category. The proportion of children in the *poor* and *below average* categories also decreased by over 5% and 20% in the respective categories following the intervention. The proportion of children in the *above average* category increased from 0% to over 15%. Following the intervention, there were also children categorised in the *superior* and *very superior* categories, in contrast to baseline. Among the control group, the proportion of children in the *very poor, poor,* and *below average* categories increased, while the proportion of children in the *average* category decreased.

Table 7.5: Intervention 2: Distribution of Locomotor Standard Score, Object-control Standard Score, and Gross Motor Quotient (GMQ) scores in each Test of Gross Motor Development-2 (TGMD-2) performance category, pre- and post-intervention

	Intervention		Control	
	Pre (%)	Post (%)	Pre (%)	Post (%)
Locomotor Standard Score				
Very Poor	0	0	0	0
Poor	3.6	1	2.5	4.9
Below Average	7.7	0.5	5.6	20.4
Average	78.5	55.4	85.2	71.6
Above Average	7.2	36.9	4.9	2.5
Superior	3.1	5.6	1.9	0.6
Very Superior	0	0.5	0	0
Object-control Standard Score				
Very Poor	1	0	1.2	1.9
Poor	10.8	2.1	5.6	17.9
Below Average	28.7	15.9	30.9	46.3
Average	57.9	68.7	58	34
Above Average	1.5	11.3	4.3	0
Superior	0	2.1	0	0
Very Superior	0	0	0	0
GMQ				
Very Poor	1.5	0	0.6	1.2
Poor	7.2	2.1	6.2	23.5
Below Average	26.2	5.6	24.1	37
Average	57.9	66.7	63.6	35.8
Above Average	0	17.4	0	2.5
Superior	0	7.7	0	0
Very Superior	0	0.5	0	0

GMQ: Gross Motor Quotient

7.5 Discussion

In Ireland, FMS proficiency and PA levels have been reported to be low among primary school aged children. As FMS have been found to be associated with PA levels and numerous health benefits, it is imperative that approaches to improve FMS are adopted among this cohort. This is the first study to examine the effect of specifically tailored interventions at improving FMS proficiency among Irish primary school children.

Intervention 1

Findings from this study suggest that although locomotor proficiency improved and object-control proficiency was maintained among the intervention group, the PA intervention was not significantly more effective than the Irish Physical Education curriculum carried out in the control school (in which no improvements in FMS proficiency were observed). Even though FMS instruction and feedback was not provided, improvement in locomotor proficiency among the intervention group may have resulted from the increased PA opportunities provided through lessons delivered by the qualified specialist, daily PA and weekly Physical Education provided by teachers. During this PA time, children engaged primarily in *huff and puff* activities and games which placed greater emphasis on locomotor skills such as running, jumping, galloping, and hopping as opposed to object-control skills. No significant change in object-control (and overall proficiency) indicates that increased PA opportunities alone may not be sufficient to improve object-control proficiency. Previous research has evaluated the effectiveness of PA interventions on motor skills, with a variety of definitions, skills and measures used across studies (Morgan et al., 2013). Therefore, this is the first study to investigate the effectiveness of a PA intervention (i.e. without an FMS focus) on FMS proficiency, and thus further research is warranted. In light of our findings and based on previous suggestions that FMS are not acquired naturally (Barnett et al., 2016; Gallahue et al., 2012; Payne & Isaacs, 2002), interventions aimed at improving FMS should include quality instruction, feedback, encouragement and practice opportunities.

Intervention 2

The multicomponent FMS intervention (Year 2) resulted in significant group-time interactions for locomotor, object-control, and overall FMS proficiency, in favour of the intervention group. Significant increases were found in locomotor standard score, object-control standard score, and GMQ score among the 6-year-old and 10-year-old intervention groups, while significant decreases were observed among the respective control groups. Results from this multicomponent school-based intervention provides further evidence for the effectiveness of FMS interventions among primary school children. Our findings are consistent with recent meta-analyses (Morgan et al., 2013), which has found significantly greater locomotor, object-control, and overall FMS proficiency levels among children following school-based FMS interventions.

Analysis of the proportion of the children achieving mastery in each of the 12 FMS provided an in-depth insight into the effectiveness of this intervention. Among the 6-year-old intervention children, following the intervention, there were increases in the proportion of children achieving mastery in 11 of the 12 FMS (with mean improvement ranging from 1.1% improvement in the leap to 34.8% in the slide). The increase in eight of the FMS were significant (run, hop, gallop, slide, jump, throw, roll, kick, and dribble) ($p < .05$) (see Table 7.4).

The mean increase in the proportion of children achieving mastery across all FMS among the 6-year-old intervention cohort was 13%, in contrast to a 7% decrease among the control group. The skills which resulted in the greatest percentage improvement in mastery levels were the slide (35%), jump (34%) as well as both the kick and the hop (22%). Surprisingly, there was a significant decrease in the proportion of children achieving mastery in the gallop. It is possible that this may be due to the young children's over enthusiasm in performing the skill at post-intervention testing, as the gallop was no longer a skill unfamiliar to them. This may have manifested in increases in the speed at which children attempted the gallop. In addition, as testing was conducted in small groups, children's patience while waiting their turn as well as the performance of their peers which preceded their own attempts may also have influenced performances. Component analysis supported this observation, with a significant decrease in the proportion of this group proficient in the component ($p < .001$, *Cochrane's Q* = 12.600), requiring '*a step forward with the lead foot followed by a step with the trailing foot to a position adjacent to or behind the lead foot*' (Ulrich, 2000).

Among the 10-year-old intervention group following the intervention, there were increases in the percentage achieving mastery in 11 of the 12 FMS (with mean improvement ranging from 3.8% in the run to 47.6% in the jump). The increase in the percentage achieving mastery in seven of the FMS was found to be significant (hop, slide, jump, catch, throw, roll, kick, and dribble) ($p < .05$) (see Table 7.4). At pre-intervention 2, the least proficient skills were the jump (3%) and roll (9%), with only 7 skills exceeding 50% mastery. However, at post-intervention 2, 10 skills exceeded 50% mastery, with the strike (25%) and the throw (46%) identified as the least proficient skills. The proportion of children achieving mastery across all FMS among the 10-year-old intervention group was 18% compared to a 5% decrease among the control group. The greatest percentage improvements in mastery levels were observed in the jump (48%), roll (47%), and dribble (39%). Surprisingly, an unexpected significant decrease in the proportion of 10-year-old children achieving mastery in the catch was found. Component analysis conducted revealed that among this group, there was a significant decrease in the proportion of children who demonstrated proficiency in the component requiring a *'preparation phase where hands are in front of the body and elbows are flexed'* (Ulrich, 2000), from 99% to 78% ($p < .001$, *Cochrane's Q* = 20.167). This may demonstrate the older children's over-confidence in their ability to catch the ball, reflected in the fact that 96% of this group did indeed catch the ball for both trials (another required component for mastery).

The positive improvements observed in the intervention groups relative to the control groups adds to the body of evidence suggesting FMS are not acquired naturally (Barnett et al., 2016). Rather, learning, practice and reinforcement are required in order to become proficient, without which, developmental delays or deficits may occur (Gallahue et al., 2012).

The significant intervention effects on FMS proficiency observed in this study may be attributed to the quality and interaction of the various FMS-based components of this intervention, including FMS-based lesson plans and posters, FMS professional development practical workshop, FMS homework as well as FMS activity breaks. Also, the quality of teaching and feedback received during sessions delivered by the qualified specialist and any additional teacher-led PA sessions (including PA and FMS initiatives) incorporating FMS-based activities and fun games, facilitated and promoted FMS development. It is through quality instruction and feedback from qualified individuals and through practice opportunities that children develop and improve movement skill patterns (Cohen et al., 2015; Gallahue et al., 2012).

Improvements in locomotor proficiency were evident based on the distribution across the TGMD-2 classifications (Ulrich, 2000) for locomotor standard score with a lower proportion of children in the intervention group in the *poor* category following the intervention, in turn resulting in greater proportions of children in the *above average* (almost 30% greater), and *superior* categories. Furthermore, at pre-intervention 2, there was no child in the *very superior* category. However, following the intervention there were children demonstrating this level of locomotor proficiency.

In terms of the improvements in object-control proficiency, the distribution of object-control standard score revealed that there was no longer any child in the intervention group in the *very poor* category and the proportion of children in the *poor* category decreased from 11% to 2%. This resulted in a higher proportion of children in the *average* and *above average* categories. Also, in contrast to pre-intervention, there were children categorised in the *superior* category following the intervention. In contrast to the locomotor standard score, there was less than 15% of the children in the *above average*, *superior,* or *very superior* categories post-intervention 2, demonstrating the greater practice, instruction and perceptual demands required to develop object-control skills. Nonetheless, these positive findings highlight the effectiveness of the multicomponent FMS intervention at improving both locomotor and object-control proficiency of children, regardless of baseline ability.

Following the intervention, 47% of children in the intervention group were classified in a higher GMQ performance category than before the intervention, in contrast to 7% of the control group. The overall improvement in FMS proficiency, following the multicomponent FMS intervention, is also reflected in a shift in the distribution of the Irish cohort across the TGMD-2 categories, to the right of the continuum.

At post-intervention 2, there was no longer any child in the intervention group in the *very poor* category and the proportion of children in the *poor* and *below average* categories decreased by over 5% and 20%. Consequently, there was an increase in the proportion of children in the *above average* category. Also, prior the intervention, there was no child in the *above average*, *superior,* or *very superior* categories. However, following the intervention, these categories accounted for over 25% of the intervention group. These findings highlight, although children may not yet have attained 'mastery' (i.e. all components present across both trials), improvements have been made in FMS proficiency across the intervention. This indicates that, despite improvement in GMQ, the cohort of Irish children require further instruction, practice and feedback to allow for continued development and improvement and to attain superior FMS levels. Based on the positive findings of this study, the implementation of the multicomponent FMS intervention delivered by a qualified specialist for a longer duration may be one such mechanism to aid this further development.

7. 6 Limitations

- A limitation of this study includes the use of unmatched intervention and control schools, in terms of both geographical location and the sex of attending children. However, it should be noted that all three schools (two urban single-sex intervention schools and one rural mixed-sex school) were in close proximity (approximately 10km) to each other. In relation to the existing sex-differences of participants across included schools, there may be developmental differences between children who attend all boys and all girls' schools and a mixed-sex school, in terms of PA choices and participation levels. It is recommended for future research that matched schools are selected based on geographical location and sex of participants, allowing for a more accurate comparison of groups.

- FMS testing, was conducted in small groups within each class group (up to 30 children) at the same time, through the use of a rotational station system. While this protocol was effective and time-efficient, it is possible that children may have been distracted during the demonstration of a skill, due to the presence of other children in their group or due to the movement of other children and testers throughout the hall. Also, as children were required to wait for their own turn to attempt the skill, children may have forgotten the visual demonstration and may also have been influenced by the attempts to perform the skill made by their peers which preceded their own attempts. Children's concentration and attention levels and their ability to be patient while waiting their turn may also have influenced performances. Therefore, it is recommended for future research that FMS testing should be carried out individually with minimal external distraction to allow a most accurate measure of FMS proficiency.
- Sessions delivered by the qualified specialist replaced the allotted weekly Physical Education time in the girls' school, while the boys' school also received a 30-minute weekly Physical Education class delivered by the classroom teacher. This difference was due to individual school preferences and was not controllable by the *Project Spraoi* Research Team. However, as each teacher was permitted and encouraged to facilitate 20 minutes MVPA daily, this may not have influenced findings but nonetheless must be considered. For future research, it is recommended that all intervention groups received similar allocated PA time to maximise the quality of study design, findings and conclusions.
- PA facilitated by classroom teachers was not monitored during the PA intervention. However, PA and FMS opportunities were monitored through the use of the FMS/PA break charts during the FMS intervention. Findings revealed that on average, classroom teachers facilitated 14.3 minutes of PA per school day (excluding two x 25 minute lessons delivered by the qualified specialist weekly). It must be noted that while teacher and students were instructed to complete

the FMS and PA charts to the best of their ability, the accuracy of reporting, due to the self-measure nature of the charts, is not known.

- Although FMS practice was monitored through the FMS homework manuals, it was not possible to ascertain how many practice attempts were made by each child at performing each skill throughout the intervention period (i.e. during sessions delivered by the qualified specialist, additional PA opportunities during school time and outside of school time including weekend activity as well as during organised sport/PA). Also, as FMS homework was recorded by self-report by children (and parents) and children often misplaced homework manuals, the accuracy and reliability of data relating to FMS practice conducted is unknown and has not been included. The introduction of FMS homework manuals also encouraged parents to participate in the FMS activities with their children. However, as FMS homework was very often recorded in the manual by the children themselves, it was not possible to ascertain the level of parental engagement.
- The order in which skills were practiced across the intervention during the sessions delivered by the qualified specialist, which was determined by each school, may be a further limitation influencing skill improvement from several perspectives. Firstly, additional opportunities to attempt the skills and technique(s) learned may be possible for children for those skills taught at the early stages of the intervention. On the other hand, the skills (and the correct technique) taught later in the intervention may be more easily remembered. However, the recap lessons at the end of the intervention reinforced the correct technique required for each of the FMS and provided further practice opportunities for each of the skills.
- Much research has previously used GMQ as a measure of FMS proficiency (Bardid et al., 2016; Burrows et al., 2014; Johnstone et al., 2017). As GMQ is based on normative data collected from a sample of 1,208 US children (Ulrich, 2000), the use of GMQ allows comparison to be made between the Irish and US samples. While classifying FMS performance based on GMQ may detect changes in FMS performance over time, it may not be a true representation of actual FMS proficiency among the Irish cohort as GMQ is based on a US sample. Future

research to develop a GMQ scale for Irish children based on normative data collected among children in Ireland is recommended.

- Zask et al. (2012) has acknowledged that there is limited research which has conducted a retention assessment of FMS to assess the long-term impact of such interventions. However, Robinson and Goodway (2009) revealed significant improvement in object-control skills among preschool children from baseline to retention, conducted six months following the intervention, in comparison to control children. Similarly, among Irish adolescents, significant improvements in overall FMS were revealed from baseline to retention conducted three months following the 8-month Y-PATH intervention (McGrane et al., 2018). These positive findings by Robinson and Goodway (2009) and McGrane et al. (2018) provide support for the efficacy of the interventions implemented. A limitation of the current research is that no retention assessment was conducted. However, future research (which will be carried out by other members of the Project Spraoi Research Team) will examine the effectiveness of this intervention using a pre-post-retention design. Such an examination will assess the long-term effects of the intervention (Roberts & Ilardi, 2003).

7.7 Conclusion

The PA intervention (without an FMS focus) improved locomotor proficiency and maintained object-control proficiency among a cohort of 6- and 10-year-old Irish primary school children, assessed using the TGMD-2. However, changes in FMS proficiency following the PA intervention were no greater than those made by the control group following the Irish Physical Education Curriculum only. The multicomponent FMS intervention delivered by qualified specialists across an academic year resulted in significant intervention effects for locomotor, object-control and overall FMS proficiency among 6- and 10-year-old Irish primary school children, when compared to the control treatment group. Aligned with recommendations by Tompsett et al. (2017), the 26-week intervention involving twice-weekly FMS and PA sessions delivered by a qualified specialist (Energizer), on-going teacher professional development, as well as an at-home practice component encouraging parental participation, was successful at improving FMS proficiency among Irish youth. The implementation of the FMS intervention, of longer duration and delivered by physical education specialists throughout the primary school years, may also promote further FMS development among children.

The current chapter presented the findings from the evaluation of two interventions; one PA and one FMS intervention. While the PA intervention had no significant impact on children's FMS proficiency, the motor skill intervention resulted in significant improvements among the intervention group relative to the control. While the current chapter also discussed the findings from these two evaluations, the next chapter summarises and discusses the main findings of the overall research process. In discussing such, a number of practical implications and recommendations for future research are also provided.

Chapter 8:

Discussion, conclusion and recommendations for future research

8.1 Discussion

This chapter will discuss each of the research hypotheses and the relevant findings revealed within the overall research process. The significance of these findings and how this research will contribute to the existing body of literature in the field will be further developed in this context. Future recommendations to improve the FMS proficiency of Irish primary school children will also be suggested while limitations of the current research will also be noted.

H*Ø1: There will no significant age and/or sex-related differences in FMS proficiency among a cohort of Irish primary school children*

Findings revealed both age- and sex-related differences in FMS proficiency in this cohort. It was found that the 10-year-old children scored significantly higher than their 6-year-old counterparts in both locomotor (medium to large effect size) and object-control subset scores (large effect size), independent of sex. In addition, a significantly greater proportion of 10-year-olds achieved mastery in two of the six locomotor skills (hop: 16.7% difference; gallop: 19.3% difference) and five of the six object-control skills (with the exception of the strike) compared to the 6-year-old cohort (difference in mastery levels ranging from 12.9% in the roll to 50.5% in the dribble). These findings suggest that older children exhibit superior FMS proficiency than younger children, which is similar to the literature worldwide (Booth et al., 1999; Bryant et al., 2014; Mitchell et al., 2013; Spessato, Gabbard, Valentini, & Rudisill, 2013).

These findings are also supported by the evidence revealed in the systematic review of the FMS proficiency levels of primary school aged children (4- to 13-year-olds) worldwide (Chapter 4). Weighted mean scores evaluated for each individual age (from 4 to 13 years) as well as for three different age ranges (including 4-8 years, 8-13 years and 4-13 years), revealed that both locomotor and object-control raw subset scores at each age/age-group were greater than that of the age/age-group preceding it.

There are several contributing factors to the age-related superiority found in FMS in the current research, which is also supported in similar populations worldwide. The additional instruction, coaching and feedback received from teachers, parents and coaches that the older children have received during their additional life years has provided them with opportunities to develop and refine their techniques and movements during practice time (which would also have been higher) leading to their greater FMS proficiency. In addition, natural maturation may also have contributed, in part, to the greater FMS as a result of physical growth and greater strength levels relative to body mass (Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2015), as well as the maturation of the nervous system (Charlesworth, 2016) facilitating greater co-ordination and limb control.

In terms of sex-related differences, the current research found that among the 6-year-old cohort, girls scored significantly higher than 6-year-old boys in locomotor score (small effect size). However, no significant difference in locomotor proficiency was found between boys and girls among the 10-year-old cohort. In the individual locomotor skills, mastery levels were higher among girls than boys in all six skills, with a significant difference in the run (p = .008). The inconsistent findings across the two cohorts examined in the current research reflect the findings in the literature, in which some research has reported superior locomotor proficiency among girls in comparison to boys (Barnett et al., 2009), while others have reported no sex-related differences (Bakhtiar, 2014; Barnett et al., 2008). Greater locomotor proficiency among girls has often been accounted for by the type of activities that girls tend to participate in, which are predominantly locomotor related activities (Hardy, King, Farrell, et al., 2010). Evidence among Irish children has also revealed this preference for locomotor based activities with dance, swimming, ballet and gymnastics among the most popular activities among girls, and less popular among boys (Williams et al., 2009; Woods et al., 2010).

In relation to object-control proficiency, boys exhibited significantly higher FMS levels than girls (large effect size) among both the 6-year-old and 10-year-old cohorts. A significantly greater proportion of boys achieved mastery in the kick, throw and roll compared to the girls. The greater object-control proficiency exhibited among boys in the current research supports the current body of literature that commonly reports greater object-control proficiency among boys in comparison to girls (Bardid et al., 2016;

Lubans et al 2010). The broadly suggested rationale for this trend is their greater participation in sports/activities that involve object manipulation (Booth et al., 2006). This greater participation sports/activities incorporating object-control skills is also evident among the Irish cohort, in which soccer, Gaelic football, hurling, rugby and basketball are among the most popular male sports (Williams et al., 2009; Woods et al., 2010) in contrast to sports involving locomotor skills among the most popular female sports (Williams et al., 2009; Woods et al., 2010).

As children have the potential to master FMS by the age of 5-7 years (Gallahue & Ozmun, 2006) and have been shown to improve FMS greatly at a young age (Mitchell et al., 2013), interventions and strategies to improve FMS proficiency among children should be introduced as early as possible among primary school aged children and implemented throughout the primary school years. To bridge sex-related differences that exist in both locomotor and object-control proficiency, it is important that boys and girls receive equal encouragement, instruction and opportunities from teachers, parents and friends to practice all FMS (both locomotor and object-control) during PE, extra-curricular activity and free play (Spessato, Gabbard, Valentini et al., 2013). Thus, the implementation of interventions aimed at increasing the FMS levels among Irish primary school children, including developmentally age-appropriate activities in which quality instruction, practice opportunities and feedback are provided to children, is recommended.

HØ2: There will be no significant difference between the FMS proficiency levels of a cohort of Irish primary school children and TGMD-2 normative data and other countries worldwide

In comparison to the normative dataset provided in the TGMD-2, locomotor proficiency (subset scores) among boys was significantly lower than that of the US boys of similar ages. In contrast, 6-year-old girls demonstrated significantly superior locomotor proficiency than their US counterparts, while no difference existed between the 10-year-old cohort of Irish and US girls. In terms of object-control proficiency, the cohort of Irish primary school children (6- and 10-year-old boys and girls) demonstrated significantly lower levels of proficiency in comparison to the children in the normative sample of similar age and sex. Overall, FMS proficiency among the Irish cohort, as indicated by the GMQ, was significantly lower than that of the US children, with the exception of the 6-year-old girls who demonstrate similar levels of proficiency to their US counterparts. Furthermore, across the seven TGMD-2 rating categories (ranging from *very poor* to *very superior*) (Ulrich, 2000), there was a significantly greater proportion of the Irish children in the *below average* and *average* categories than the US normative sample, while there was a significantly lower proportion categorised in the categories at the upper end of the continuum (i.e. *above average*, *superior* and *very superior*). As the US normative data was collected in 1997-1998, these findings suggest that FMS proficiency among Irish primary school children is lower than that of previous generations.

Cultural differences which exist between Ireland and US may contribute to the differences in FMS proficiency exhibited. While FMS has been tested worldwide using the TGMD-2, it must be noted that it was developed in the United States and includes skills identified as culturally relevant among the US population. For example, skills such as the catch, throw, strike and dribble are relevant for the most popular sports in the US including American Football, baseball/softball and basketball (Wallerson, 2014). In contrast, Gaelic Football, soccer and dance are among the most popular sports among Irish primary school children (Woods et al., 2010) which is reflected in this research as the kick was identified as the object-control skill with the highest mastery levels (proportion of children achieving mastery). Also, the locomotor proficiency demonstrated by the Irish girls may possibly be influenced by the restricted use of equipment during lunch times in the girls' school, which limited them to participate in locomotor activities only, during these times. Furthermore, it has been reported that dance (a locomotor activity) is the most popular extra-school sport and the second most popular extra-curricular activity among primary school girls in Ireland (Woods et al., 2010).

Nonetheless, the skills and components required for proficiency in 11 of the 12 skills (with the exception of the strike) of the TGMD-2 can be applied in an Irish context. The strike technique, however, which mirrors the fundamental technique required for a baseball strike is different to that required in hurling/camogie (a striking sport, one of the national games of Ireland), which requires a different hand-grip. Consequently, proficiency levels in the strike may be influenced by children's exposure to hurling/camogie, which may have contributed to children's lower object-control and overall FMS proficiency relative to their US counterparts. It is evident that sporting cultures have an influential role on FMS proficiency among young children.

Many other factors may contribute to the low FMS levels exhibited among Irish primary school children relative to the US norms. These include low physical activity levels, with only 19% of children reaching the recommended 60 minutes of moderate-to-vigorous physical activity daily (Woods et al., 2010). Furthermore, the time spent in PE in Irish primary schools is low. While the recommended level of weekly PE is 60 minutes, it has been reported that only 46 minutes per week PE is received by Irish primary school children (European Commission/EACEA/Eurydice, 2013). In contrast, US children (in 1997-1998 at which data collection from the US sample was conducted) were recommended to receive daily PE classes and it was found that elementary children received 50-200 minutes PE weekly (National Association for Sport and Physical Activity, 1997). Furthermore, this PE was delivered by a PE specialist and/with the classroom teacher (National Association for Sport and Physical Activity, 1997) in contrast to the classroom teacher only in Ireland. The restriction on PA in the single-sex girls school included in this research must also be noted. As girls were not permitted to go outside during first school break and with a restriction on equipment use during second school break the girls attending attending the single-sex girls school had limited opportunities to practice and develop FMS (most notably object-control skills).

Mastery levels similar to those reported among 5- to 12-year-old New Zealand children (Mitchell et al., 2013) were exhibited in the current research. The proportion of the cohort of Irish children achieving mastery was lower than that of the New Zealand children in the catch, dribble, strike, slide, jump and the hop (six out of 12 FMS). The kick was the only skill in which Irish children demonstrated greater proficiency than their southern hemisphere counterparts. This is suggested to be due the high levels of participation in sports that involve kicking in Ireland, most notably Gaelic Football and soccer, which have been found among the most popular activities among Irish primary school children (Woods et al., 2010). Among the cohort of Irish primary school children, the run was the skill with the highest mastery level, which was also found among the New Zealand children. Similarly, the jump was the locomotor skill with the lowest level of mastery among both the Irish and New Zealand children. This may be due to the complexity of this skill which involves several attributes of physical ability including strength for take-off and postural control and also co-ordination and balance during flight and landing (Haibach et al., 2011).

In comparison to the global FMS levels reported in the systematic literature review (Chapter 4), the cohort of 6-year-old Irish children (both boys and girls) demonstrated greater locomotor and object-control proficiency, with the exception of 6-year-old girls for object-control proficiency based on mean subset scores (Table 8.1). Similarly, the 6-year-old Irish children achieved a higher GMQ (indicating overall FMS proficiency). However, when classified into TGMD-2 performance categories, both Irish and global levels were considered *average* (GMQ range: 90-110). Among the 10-year-old cohort, the FMS proficiency levels (locomotor and object-control) were greater than those of children worldwide, as found in Chapter 5 (Table 8.1). No published research, satisfying the inclusion criteria of the systematic literature review conducted in Chapter 4, included the evaluation of the GMQ of 10-year-old children. Nonetheless, in comparison to the 8-13 years age group (GMQ score: 82.4 ± 8.6), the cohort of 10-year-old Irish primary school children (boys and girls) achieved a greater GMQ score. However, the GMQ score achieved by the 10-year-old boys in the current study and the worldwide 8-13 years age range (Chapter 5) were both classified as *below average* based on TGMD-2 norms. In contrast, the overall FMS proficiency of the 10-year-old girls in the current study was classified as *average*.

These comparisons suggest that Irish primary school children may exhibit greater FMS proficiency than children of similar ages worldwide. However, FMS proficiency among the primary school children in the current research and worldwide fail to exceed *average* levels according to the TGMD-2 norms, despite the potential to master FMS between the age of five and seven (Gallahue & Ozmun, 2006).

Table 8.1: Comparison of FMS proficiency levels of the cohort of Irish primary school children and global levels (evaluated in Chapter 5)

	LOCO Subset Score		OC Subset Score		GMQ Score	
	n	**Mean (SD)**	**n**	**Mean (SD)**	**n**	**Mean (SD)**
6-year-olds						
Boys*	52	37.6 (4.2)	52	32.0 (4.9)	52	97.7 (7.2)
Girls*	50	40.3 (3.8)	50	26.0 (4.8)	50	100.9 (10.3)
Worldwide**	1132	32.9 (5.1)	1109	27.0 (4.3)	495	92.7 (8.3)
10-year-olds						
Boys*	58	41.2 (3.5)	58	40.3 (3.5)	58	87.5 (9.0)
Girls*	43	41.9 (4.0)	43	37.4 (4.3)	43	92.3 (9.3)
Worldwide**	606	35.7 (5.4)	606	34.2 (3.9)	-	-

*sample from the current study (Chapter 5)
**sample from systematic literature review (Chapter 4)
LOCO: Locomotor, OC: Object-control, GMQ: Gross Motor Quotient

The less than satisfactory FMS levels and the existing high levels of overweight/obesity and low levels of PA among primary school children in Ireland and worldwide (WHO, 2018a, 2018c) highlight the necessity for interventions, which have been found to improve FMS proficiency. These interventions and strategies are recommended to be introduced on a national scale (e.g. the inclusion of an FMS focus in PA policies, plans and strategies aimed at improving health and PA among children) and also at a local level including primary schools, local sporting organisation and other relevant community settings. As children have been shown to improve FMS greatly at a young age (Mitchell et al., 2013), it is important that these interventions are introduced as early as possible among primary school aged children.

HØ3: There will be no significant association between perceived movement skill competence and PA levels, with respect to age and sex among a cohort of Irish primary school children

The findings of the current study revealed that 6-year-olds (boys and girls) accurately perceived their locomotor proficiency but overestimated their object-control and overall FMS proficiency. Among the 10-year-old cohort, both locomotor and overall FMS proficiency was underestimated, while object-control proficiency was overestimated.

The overestimation of proficiency may prove beneficial, resulting in high levels of motivation among children, promoting greater effort and practice attempts, thus driving the acquisition of actual competence (Lopes, Barnett, & Rodrigues, 2016; Weiss & Amorose, 2005) and subsequently PA levels. Evidence in the current research supports this, with perceived object-control and perceived overall FMS competence found to be significant predictors of MVPA (after adjusting for age and sex). Therefore, the early primary school years, when perceived competence and motivation levels are high, may be a critical and optimal period in which attempts and approaches to enhance FMS proficiency levels among children should be implemented. The overestimation of object-control proficiency, in particular, among both the 6- and 10-year-old cohorts may be used to promote the development of higher levels of actual object-control proficiency (and participation in PA involving these skills), which has been found to be lower than locomotor proficiency among primary school children worldwide (Chapter 4) and notably in Ireland (Chapter 5). The underestimation of FMS competence among the 10-year-old cohort in the current research is worrying as it may negatively influence motivation (Bagøien & Halvari, 2005) and result in disengagement from PA and activities/sports that promote actual FMS development. Furthermore, as PC has been found to track into adolescence (Barnett et al., 2008), this disengagement from PA may continue as children age.

Approaches to achieve and sustain high levels of perceived movement competence should be considered and included within interventions aimed at improving children's FMS proficiency and/or PA to promote a positive engagement in PA. The use of a mastery climate is one such intervention approach (Morgan et al., 2013) found to be effective. This approach, in which the difficulty level of activities/tasks may be individually selected by each child, will allow children to engage in appropriately challenging, yet achievable, performance attempts to increase PC and motivation to participate in PA and sport, facilitating actual FMS development. These interventions may help increase both the perceived competence and existing FMS levels children revealed in the current research, and also help combat the high levels of sedentary behaviour reported among Irish children (Tremblay, 2014).

HØ4: There will be no significant difference in children's FMS proficiency following a physical activity intervention delivered across one academic year

Following the implementation of the PA intervention among a cohort of Irish primary school children, significant improvements were observed in locomotor proficiency (small effect size), while object-control and overall FMS proficiency was maintained. However, the PA intervention was not significantly more effective at improving FMS proficiency than the Irish PE curriculum delivered in the control school (in which no changes in FMS proficiency were observed). Improvement in locomotor proficiency among the intervention group may be due to increased PA opportunities provided through Energizer-led lessons, daily PA (which was encouraged) and weekly PE provided by teachers. During these bouts of PA, children engaged primarily in *huff and puff* (MVPA) activities, with greater emphasis on locomotor skills such as running and jumping, as opposed to object-control skills. The lack of improvement in object-control (and overall) proficiency suggests that increased PA opportunities alone may not be sufficient to improve object-control proficiency, providing further support for the notion, commonly proposed in existing literature, that children do not acquire FMS naturally (Gallahue & Ozmun, 2006; Pang & Fong, 2009; Payne & Isaacs, 2002). Rather, quality instruction, feedback as well as quality practice opportunities are all essential elements to increase FMS proficiency (both locomotor and object-control) among children (Gallahue et al., 2012).

These findings in the current research are similar to those of several previous studies (Boyles-Holmes et al., 2010; Graf et al., 2008; Salmon et al., 2008) that have investigated the effectiveness of a PA-based intervention, in that some improvements in the FMS proficiency levels were observed. Boyles-Holmes et al. (2010) found improvements in two of the three skills assessed (forehand strike and lift and carry) among both 4th and 5th grade children; however, improvements in the leap were only found among the 4th grade children. Similarly, Graf et al. (2008) reported that significant improvements were only evident in two of the four motor skills of the KTK assessed (balancing backwards and lateral jumping but not one-legged obstacle jumping nor sideways movements). Furthermore, improvements observed by Salmon et al. (2008) in six FMS using the Department of Victoria resource (Department of Education, Victoria, 1996) were reported among girls, but not boys. Therefore, findings in the current research contribute to the existing body of literature reporting the effectiveness of PA-based interventions at improving some aspects of FMS proficiency. However, limitations within the current research should be considered (see Section 8.4). Based on existing findings and literature, it is recommended that interventions aimed at improving FMS should include quality instruction, feedback, encouragement and sufficient practice opportunities.

A process evaluation of the PA intervention delivered across AY14/15 was conducted to examine to investigate the progress of the project from a school and staff perspective. Several aspects of process evaluation were carried out within this research, including a staff meeting/focus group between school staff and the Energizer at the end of the PA intervention (June 2015). During this focus group meeting, facilitated by the Energizer, staff were divided into small groups of 3-4 and following a 10-minute discussion between group members, an evaluation worksheet was completed by each group, which asked the following questions: (i) What has worked well so far?, (ii) What are the barriers to completing 20 minutes PA with your class daily? and (iii) what ways can we (the Energizer and *Project Spraoi*) help you and you class achieve 20 minutes PA each day? Following a whole group discussion, findings were relayed to the Energizer who collated the data on a flipchart. Data collected identified positive aspects of the intervention as well as areas in which teachers stated that they required further assistance. Some of the positive feedback from this discussion included:

- improvement in fitness levels evident
  ("fitness levels and energy levels improved", "becoming aware of their own fitness and how it has improved")
- all-inclusive
  ("kids are constantly active", "all children involved")
- PA enjoyment
  ("lessons are fun and organised", "kids enjoy the classes" "children are very motivated and highly content with lessons", "energized")
- encouraged PA daily
  ("it has raised awareness to be active daily")

- improvements in spatial awareness and concentration
  ("spatial awareness and concentration have improved")

During this PA intervention, while it was encouraged that children should participate in 20 minutes of PA daily, the time engaged in PA outside of Energizer-led sessions was not monitored. Therefore, it was not possible to evaluate an accurate measure of how much time was spent engaged in PA during the school day/week. Also, anecdotally, as teachers were not required to monitor the provision of extra PA nor was it mandatory, it often was not facilitated due to time constraints and demands and pressure of the Irish curriculum. Barriers identified (during the focus group meeting) in completing the 20 minutes of physical activity daily were "time constraints" and the "lack of facilities". To aid teachers and classes achieve the target of 20 minute of MVPA during the school day, teachers suggested the need for "help with gymnastics", "idea for quick and easy activities – both inside and outside the classroom", "more ideas for short energy breaks suitable for the classroom" and a "booklet of activities".

Findings from the evaluation of the effectiveness of this intervention, as well as those revealed in the process evaluation, were subsequently used in the design and development of the multicomponent FMS intervention (including the development of additional resources, the introduction of classroom FMS/PA break charts which monitored the PA facilitated by teachers each day, and the delivery of several professional development workshops). Components of the multicomponent FMS intervention are described in detail in Chapter 7.

HØ5: There will be no significant difference in children's FMS proficiency following a 26-week multicomponent FMS-based intervention

Following the 26-week multicomponent FMS-based intervention, significant improvements in locomotor, object-control and overall FMS proficiency were found among the intervention group, with significant decreases were evident among the control group. These findings support the general conclusions of a systematic review of 22 articles, which report the effectiveness of school-based motor skill interventions at improving FMS proficiency (both locomotor and object-control) among children

(Morgan et al., 2013). The intervention group achieved significantly greater locomotor and object-control standard scores as well as GMQ score (all large effect sizes) following the intervention. According to TGMD-2 performance ratings, the intervention group post-FMS intervention are classified in the *average* category (Ulrich, 2000). In comparison to FMS levels of primary school children worldwide (4- to 13-year-olds) (Chapter 4), which are also categorised as *average* (SS range: 8-12, GMQ range: 90-110), the intervention cohort at post-FMS intervention had greater standard scores and GMQ, suggesting greater locomotor, object-control and overall FMS proficiency among the intervention cohort than primary school children worldwide (Table 8.2).

Table 8.2: Comparison of Locomotor SS, Object-control SS and GMQ of the intervention group following the FMS intervention and worldwide FMS levels (as reported in Chapter 4)

	LOCO SS		OC SS		GMQ Score	
	n	**Mean (SD)**	**n**	**Mean (SD)**	**n**	**Mean (SD)**
Post FMS Intervention*	195	11.7 (2.1)	195	9.8 (2.3)	195	104.5 (10.5)
Worldwide (4-13 years)**	3667	9.4 (1.3)	4493	8.3 (1.1)	4019	91.3 (7.7)

*sample from the current study (Chapter 5)
**sample from systematic literature review (Chapter 4)
LOCO: Locomotor, OC: Object-control, SS: Standard Score, GMQ: Gross Motor Quotient

Further evidence for the effectiveness of the multicomponent FMS intervention in the current research was found, with 47% of children in the intervention group classified in a higher GMQ performance category (GMQ range: *very poor* to *very superior*) than prior to the intervention, in contrast to 7% of the control group. Among both 6-year-old and 10-year-old intervention groups, the percentage of children achieving mastery increased in 11 of the 12 skills tested, with significant improvements in eight skills among the 6-year-olds and in seven skills among the 10-year-olds. The mean improvement across all FMS among the 6-year-old cohort was 13%, with the greatest improvement evident in the slide (35%), jump (34%) and both the kick and hop (22%). Among the 10-year-old cohort, the mean improvement across all FMS was 18%, with greatest mastery percentage improvements observed in the jump (48%), roll (47%) and dribble (39%).

The significant improvements in FMS proficiency following the intervention may be attributed to the quality and interaction of the various intervention components, including the delivery of quality instruction, practice opportunities and feedback which are required for FMS improvement (Cohen, Morgan, Plotnikoff, Callister, et al., 2015). Through Energizer-led sessions and additional teacher-led sessions, quality instruction, practice time and feedback were provided to the children. The professional development FMS practical workshops, as well as the distribution of various FMS resources aimed to improve teachers' ability to facilitate appropriate FMS-based lessons and provide effective instruction and feedback (Lander et al., 2017; Morgan et al., 2013), may have further aided improvement in children's FMS proficiency. Furthermore, practice opportunities facilitated through the requirement to complete daily FMS homework specified in the FMS homework manuals, which also encouraged parental involvement, may also have contributed to FMS development. The findings in the current research provide further evidence that interventions delivered by specialists, in conjunction with home practice and involvement from parents, are more effective at improving FMS than PE alone (Tompsett et al., 2017).

Given that the intervention was multi-component, it is difficult to distinguish between the effective and non-effective components (if any). While the process evaluation revealed that teachers felt that the Energizer played a key role in the success of the intervention, an intervention in which only the intervention resources (i.e. no Energizer-led sessions) and professional development workshops were distributed and delivered to the teachers should be evaluated to compare findings. This could also be conducted with each of the remaining components to assess the effectiveness of the intervention without each component (i.e. to evaluate the importance of each of the components). However, it may be that it was an interaction of all the components together that brought about the intervention effects. Furthermore, a more in depth process evaluation of what children, teachers and parents felt were the most effective components to bring about changes in FMS proficiency should also be considered. Such process evaluation may include the respondents ranking the intervention components in order of increasing effectiveness (in their opinion) and/or identifying whether they felt components were effective or not at all.

The effectiveness of this multicomponent FMS intervention among a cohort of Irish primary school children, as well as previous evidence of the effectiveness of school-based motor skill interventions (Logan et al., 2011; Morgan et al., 2013) at improving FMS, would suggest that FMS interventions should be implemented in all primary schools nationwide. The process evaluation of the multicomponent FMS intervention in the current research also provides support for the widespread implementation of this intervention across a larger geographical area. At the mid-point (*n*=24) and end of the multicomponent FMS intervention (*n*=27), teachers and staff from the intervention schools completed questionnaires independently. In addition, following parental consent, all children from the intervention classes completed a write and draw task, while randomly selected children (*n*=8) also completed a semi-structured interview. Throughout the multicomponent FMS intervention, weekly FMS practice and PA facilitated by teachers was also recorded in the form of the FMS and PA charts (Appendix D.5).

An evaluation of the questionnaire completed at both mid-point (Table 8.1) as well as the end-of-intervention review (Figure 8.1), provides support for the feasibility to facilitate 20 minutes of daily PA despite academic pressures, with the majority of teachers agreeing/strongly agreeing that delivering the workload involved in the intervention and delivering 20 minutes MVPA daily was manageable, and that every effort was made to facilitate this throughout the year.

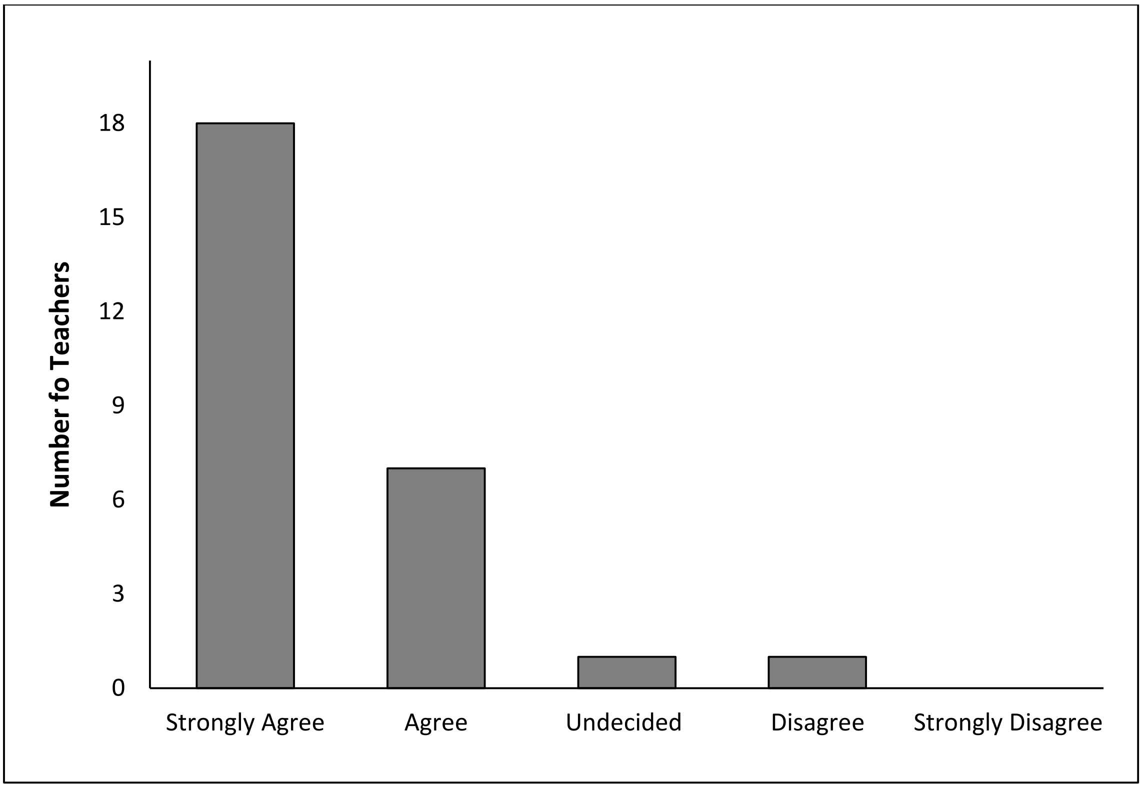

Figure 8.1: Number of teachers who strongly agreed, agreed, were undecided, disagreed or strongly disagreed with the statement, *'I found the workload involved with Project Spraoi this year manageable'*

Furthermore, results of the FMS/PA chart monitoring system revealed that on average, teachers facilitated 14.3 minutes of PA per school day (which did not include Energizer-led lessons) across the duration of the intervention. Although, this reveals that teachers (on average) did not reach the target of 20 minutes of PA daily, this evidence in conjunction with the 2 X 25 minute (i.e. additional 50 minutes) Energizer-led sessions per week, suggests that facilitating 20 minutes of PA per day for primary school children is achievable. It must be noted that while teacher and students were instructed to complete the FMS and PA charts to the best of their ability, the accuracy of reporting, due to the self-measure nature of the charts, is not known.

The evaluation of the questionnaires at mid-point also provides evidence to suggest that the intervention resulted in improvements in attention, fitness levels and teacher confidence as a result of the intervention (Table 8.3).

Table 8.3: Number of teachers who responded 'Strongly Agree' or 'Agree' in several questions of the FMS intervention mid-point questionnaire

	Strongly Agree/Agree (no. of teachers)
Delivering the physical activity sessions every day for 20 minutes is manageable	18/24 (75%)
I make every effort to deliver 20 minutes of extra physical activity every day	21/24 (88%)
After I deliver 'Huff & Puff' my students were more attentive in class than usual	16/24 (67%)
As a result of Project Spraoi I have noticed an improvement in my students' fitness levels	22/24 (92%)
I am confident to deliver FMS activities on my own on the days that the Energizer is not there	23/24 (96%)

Other positive themes identified from the questionnaire at mid-point, through the expression of positive comments from the teachers included: (i) children's enjoyment of lessons and activities, (ii) increased awareness of the importance to be physically active among students and staff, (iii) enhanced fitness, physical ability and confidence in performing physical activity and (iv) increased concentration levels. An sample of these comments are below:

- *"Project Spraoi has been single-handedly the best thing to happen to this school" (5th class teacher (1) – boys school)*
- *"Children more active. Physical activity benefits are recognised by the children. Improvement in ability and aerobic ability visible. Confidence in taking part in activities increased" (5th class teacher (2) – boys school)*
- *"fun, age-appropriate and can be used in other curricular areas" (Senior Infant teacher, girls school)*

The evaluation of the write and draw task also revealed children's enjoyment in taking part in the intervention. For the write and draw task, children from the testing classes were asked to draw a picture and write down *'What Spraoi means to me….'* (Appendix F.2). Many of the pictures depicted children, outside (in the sun), performing some form of physical acitivity, while 'fun', 'active', and 'healthy' were the most commonly used words to describe what Spraoi meant to the children. Figure 8.2 presents a sample of the findings from this task (see Appendix F.2 for additional samples). Findings from the semi-structured interviews with children (*n*=8) also found that children enjoyed participating in the project, with six out of eight (75%) acknowledging they would be 'sad' or 'disappointed' if *Project Spraoi* would not continue in the school, while all of the teachers who completed the end-of-intervention review either 'strongly agreed' (*n*=26) or 'agreed' that they would 'Like Project to continue next year'.

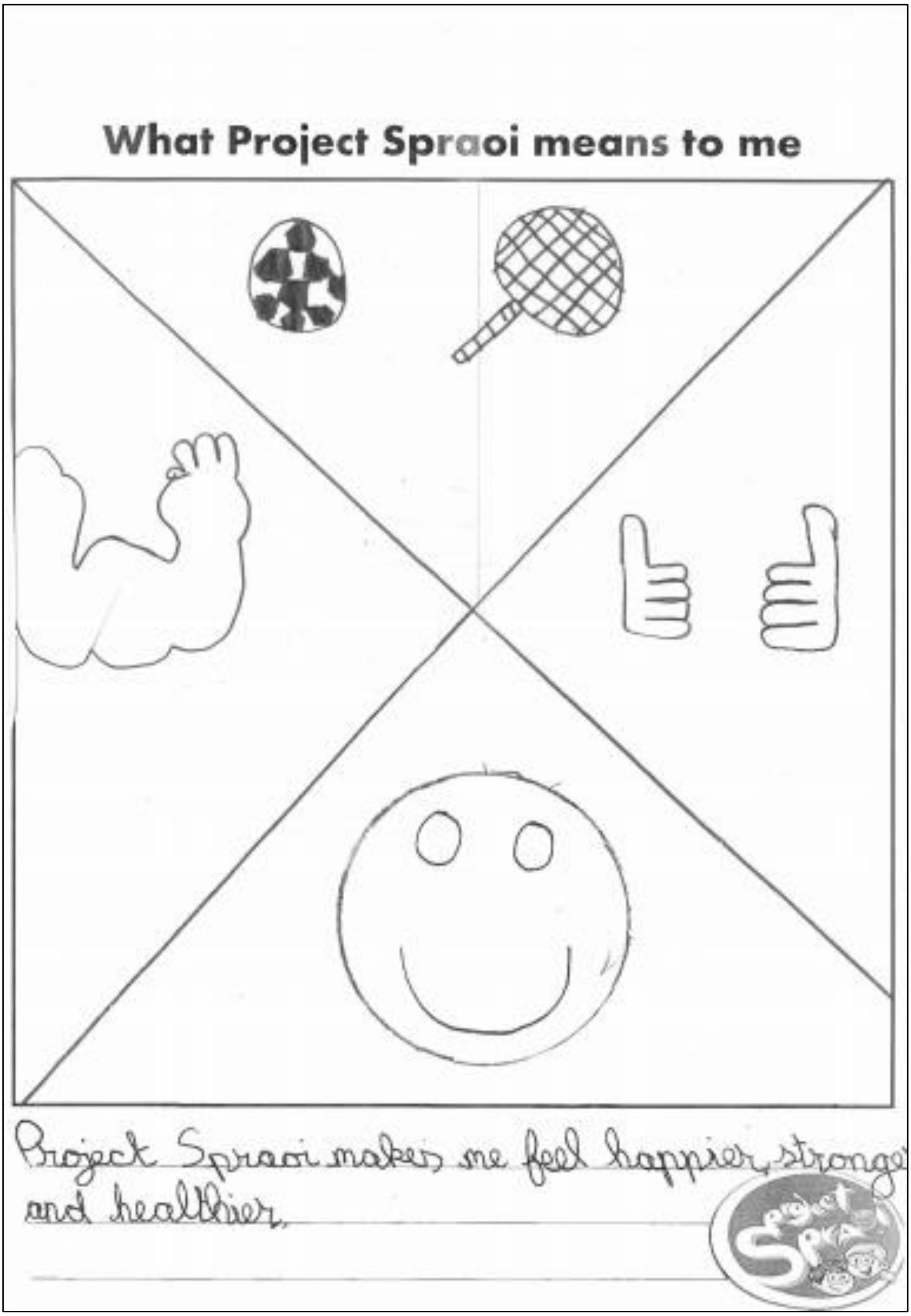

Figure 8.2: A completed write and draw process evaluation sheet by a 5th class girl

As well as the identification by teachers of an increase in children's awareness of the importance of PA, children's awareness of the importance of FMS was also revealed in the semi-structured interviews. All eight children acknowledged that FMS are important, considered by two children as 'really important', five children as 'very important' and one child as 'important enough'. In addition, when asked why they thought FMS were important, answers included:

- *"Because if you ever want to play a sport in the future you have to be good at those skills and they are skills that will help you to do loads of different things"* (5th class, girl)
- *"Because as you're growing up you might stop certain hobbies and drop certain sports so it's very important that as you get older you still have those skills so if you decide to play sports again later on in life you can pick them back up again"* (5th class, girl)
- *"Anyone who does a lot of exercise you need to be able to do the right skills"* (5th class, boy)
- *"Because you would get more fit and then you would be healthier"* (1st class girl)
- *"To make us fit and so that we are good at them when we get older"* (1st class, girl)

In the end-of-intervention review, staff were required to rate the quality of the project in terms of physical activity content and Energizer capabilities, with results displayed in Table 8.4.

Table 8.4: Quality ratings of physical activity and Energizer capabilities by teachers

	Very Good	Good	OK	Poor	Very Poor
PA content	27	0	0	0	0
Energizer capability	27	0	0	0	0

The high quality rating received for the content of the project was also mirrored in the overall comments provided through the end-of-interview questionnaires. Some of the positive aspects of the project that were echoed by several teachers included the physical activity breaks, initiatives and competitions as well as the homework manuals. The presence of the Energizer was recognised as a major facilitator of the project (noted by 15/22 teachers) with reference to the importance of the role of the Energizer for the successful implementation/sustainability of the project as well as the enthusiasm, energy, professionalism and rapport with the students. The important role and presence of a PE-specialist (i.e. the Energizer) for successful intervention delivery, has been highlighted by Tompsett et al. (2017), who reported that interventions most consistently associated with improvements in FMS include those delivered by a PE specialist, among other elements (adopting a multi-disciplinary approach, of long duration (> 6 months), providing multiple sessions per week and those incorporating parental involvement). The findings in the current research add further support to the existing body of literature in the area of FMS, emphasising the importance of a PE-specialist/PE teacher in the delivery of FMS and PA interventions.

In addition to improving children's FMS, the intervention was also empowering for teachers as process evaluation revealed that 62.5% of teachers agreed and 37.5% strongly agreed with the statement '*I am confident to deliver FMS activities on my own the days that the Energizer is not there'.* Furthermore, 79% of teachers strongly agreed and a further 21% agreed with the statement '*I think that the activities delivered by the Energizer are appropriate and easy to manage with my class'.* While the process evaluation found that teachers felt empowered, there was no evaluation of teacher's actual competence in delivering FMS sessions. Future research that aims to both educate and empower teachers should include both an evaluation of teacher's actual and perceived competence in delivering FMS sessions.

The findings of the process evaluation reveal that, not only was the intervention effective at improving children's FMS, but the structure, content and delivery of the intervention was identified as extremely positive by both teachers and children.

8.2 Practical Implications

Based on the findings revealed in the current research, several practical implications are suggested.

Specialist-Led Multi-Component FMS Interventions

- The effectiveness of the multicomponent FMS intervention among a cohort of Irish primary school children, as well as previous evidence of the effectiveness of school-based motor skill interventions (Logan et al., 2011; Morgan et al., 2013) at improving FMS, would suggest that FMS interventions (such as this) should be implemented across all primary schools in Ireland. Not only was this intervention effective at improving the FMS proficiency among the cohort of children, but it was viewed as *"single-handedly the best thing to happen to this school" (5th class teacher (1) – boys school)*, further supporting its widespread implementation across a larger geographical area.

- International best practice has identified the presence of a PE-specialist as an integral component to the successful implementation of effective interventions (Morgan et al., 2013; Rush et al., 2016; Tompsett et al., 2017), which was also acknowledged by the classroom teachers in their evaluation of the FMS intervention in the current research. The majority of teachers specified that the role of the Energizer was a primary facilitator of the successful intervention, while all teachers (*n*=27) rated the Energizer capabilities as 'very good' (highest rating possible), highlighting the importance of the existence of a PE-specialist in the delivery of the intervention. However, at present in Ireland, it may not be feasible to employ Energizers (as an additional staff member) in each of these schools due to the associated cost. However, Project Energize funded by Sport Waikato in New Zealand, from which the current interventions were adapted and modified, in which Energizers are responsible for multiple schools, has been found to be cost-effective and sustainable (in existence >10 years). The average cost of the Project Energize intervention for each child has been reported to be 40-45 New Zealand dollars (approx. €24-27 per year) (Rush et al., 2012; Rush et al., 2016). Subject to the acquisition of relevant funding from governing bodies and/or health boards, the authors suggest the employment of Energizers who would deliver this intervention in 2-3 schools each across an academic year over a smaller geographic area (e.g. in schools from one county). Other funding opportunities to employ a qualified specialist include local sponsorship, school funding (which would be shared among all participating schools), parent contribution and/or fundraising events. If found to be an effective and feasible approach to improve the FMS proficiency of children, it is suggested that this strategy and intervention be implemented across all schools nationwide. This approach, in which the Energizer is responsible for multiple schools, has been implemented by Project Energize and has been found to be successful. However, in contrast to Project Energize (Rush et al., 2012; Rush et al., 2016), funding for such an approach may not be available in an Irish context. Therefore, other avenues to increase the FMS proficiency of primary school children must be explored, including the upskilling of existing and trainee teachers, sports coaches in local sporting organisations in the area of FMS, an increase in the provision of FMS during PE and within the Irish PE curriculum, the inclusion of an FMS component within the Active School Flag Award scheme and/or the dissemination of useful FMS resources to schools, sporting organisations and teams and community groups.

<u>FMS Development at School</u>

- It is suggested that the provision for PE within the curriculum be increased. At present, within the Irish Primary Curriculum (Department of Education and Science, 1999), Physical Education is allocated only one hour per week (which is equivalent to a mere 4% of teaching time). In contrast, Arts Education, Social Environmental and Science Education (SESE) and Religious Education (RE), all of which are also not included in the core literacy and numeracy subjects (English, Irish and Mathematics) are allocated more hours per week than PE (with three hours allocated for both Arts Education and SESE and two hours allocated for RE) (McCoy, Smyth, & Banks, 2012). Despite the overcrowded curriculum, greater allocation of PE time and resources should be prioritised to promote the general health and wellbeing of primary school children.

- Evidence from the current study and previous research has shown that PE-specialist teachers are effective at improving FMS among children (Starc & Strel, 2012). Results from the process evaluation in the current research also highlight the importance of the role of the Energizer, with the majority of teachers acknowledging the presence of an Energizer/PE-specialist as a major facilitator of the project. However, it is also essential that teachers responsible for delivering PE, either classroom or PE-specialists, are provided with extensive and regular professional development in the area of FMS (Morgan et al., 2013), which should include how the development of FMS may be integrated through the existing PE strands. Recently, the Professional Development Service for Teachers (PDST) have developed the 'Move Well, Move Often' programme and resource, which aims to provide professional development in physical literacy (through FMS) (Professional Development Service for Teachers, 2018). The resource includes a Teacher Guide and three Activity Books and additional material including videos and sample lessons are also included. Phase 1 of the programme explores locomotor skills and Phase 2, which is currently taking place explores the stability skills, especially through the dance and gymnastics strands. Although these training and professional development opportunities are available, each school may only nominate two teachers to attend the seminars. It is suggested that training/FMS professional development should be mandatory for all primary school teachers, which may be provided during compulsory professional development hours, which teachers must complete in school (Department of Education and Skills, 2017b), delivered by a qualified professional or FMS expert. It is also recommended that an examination on the content delivered through this training (consisting of both a written and practical element) must be completed with an adequate standard required to pass. For those who fail the examination, additional training must be undertaken and the examination repeated until the required standard is achieved, as is the current protocol in order to complete the Higher Diploma in Education (The Teaching Council, 2017).

- Currently, in the teacher training colleges of Ireland, limited PE training is provided. It is suggested that extensive and additional PE and FMS training should be delivered in these teacher training colleges to upskill and increase confidence among pre-service teachers. For example, in one particular teacher training college, PE included in a module called 'Drama and PE' accounts for only 10 of the 120 programme credits (8%) across the compulsory subjects of Year 1 and 2, with a large amount of the time in Years 3 and 4 spent teaching in schools. Similarly, in another college, Physical Education, which is included in the 'Social, Personal, Health and Physical Education' module, is only provided in two of the eight college semesters. Research worldwide has also found that classroom teachers have often expressed dissatisfaction with their PE teacher training (Decorby et al., 2005; Morgan & Bourke, 2005), stating that more extensive training and of longer duration is required. The importance of increasing teacher confidence and competency in delivering effective PE through the extensive training suggested (for in-service and pre-service teachers) is vital as research has shown low confidence, inadequate training and limited support and resources have been found to be major barriers to successful delivery (Curtner-Smith, 1999; Decorby et al., 2005; Graham, 1991; Morgan & Bourke, 2005).

- Findings in the current research suggest FMS proficiency among Irish primary school children is low (Chapter 5) and, as a result, an increase in the provision for FMS during PE time is warranted. Through the current Irish PE curriculum strands including Games, Athletics, Gymnastics, Dance, Outdoor Adventure and Aquatics (Department of Education and Science, 1999), there is significant scope and opportunity for the development of FMS. However, it has been found that Irish primary school PE is dominated by the Games strand (Woods et al., 2010) with anecdotal evidence suggesting that large sided games are prominent. Given the lack of compliance with the recommended curriculum, but yet available scope for FMS development during PE, it is recommended that the curriculum be implemented and monitored more closely and adequate training in the area of FMS provided for teachers. Furthermore, teaching of both FMS and fundamental game skills (FGS) at the same time should be encouraged. Very often FMS are taught in isolation during early childhood and games skills taught during late childhood. However, Smith (2016) suggests that teaching both FMS and FGS at the same time, in a complementary way, would be more beneficial than either method alone.

- Bi-annual formal assessments of FMS proficiency among children should be introduced (in September and January) to monitor proficiency levels among children and assess progress over time, which would provide encouragement for primary school teachers and parents to improve the FMS of children and also provide additional motivation to children to learn FMS and aim to become proficient. Classroom teachers or other staff members (e.g. special needs assistants, learning resource teachers, principal, PE-lead teacher or teachers of younger classes who finish one-hour earlier than older classes), following adequate training in test administration and scoring, would assess the FMS proficiency of children in groups of 3-4, using the TGMD-2. Performances would be video-recorded and scored retrospectively by each class teacher during compulsory professional development time. The initial assessment each year would establish the FMS levels of the children and provide a baseline level which may aid teachers in the development of appropriate PE lessons to target FMS levels. The second assessment each year would investigate any changes in FMS proficiency and evaluate the effectiveness of the PE lessons at improving the targeted FMS. Findings from the second assessment may guide the development of PE/PA lessons for the remainder of the school year. Furthermore, each individual assessment may highlight skills or particular aspects of skills that require further work and development, from which specific training/exercises may be prescribed. The introduction of such an assessment across all primary schools nationwide would provide age- and sex-specific FMS reference data from which comparisons between children (as well as between schools/counties/provinces etc.) can be made, which may aid the development of Irish-specific FMS standards expected to be reached at each age and may be used classify FMS proficiency among Irish children. Longitudinal data may also be used to assess motor development across the primary school years. To date, Ireland is one of only three European countries not administer a PE/FMS grading system (European Commission/EACEA/Eurydice, 2013).

- A further recommendation is the introduction of an FMS competency component within the current Active School Flag award (Department of Education and Skills, 2018), which is awarded to schools that strive to achieve a physically educated and physically active school community. At present, this award scheme assesses the following three areas: Physical Education, Physical Activity and Partnerships. This additional component would encourage children to engage in FMS practice and encourage teachers to deliver quality instruction and feedback to aid FMS development. Evidence of approaches and attempts to improve the FMS proficiency of the children would be required in order to successfully satisfy the requirements of this aspect of the award.

FMS Development in the Community/Outside School

- It is suggested that the digital FMS teaching tool, titled 'Get Active, Get Moving, Be Healthy!' (Appendix B), developed during the course of the current research should be distributed to schools, colleges, coaching organisations and sporting clubs nationwide. The use of digital technology in PE has gained much attention in recent times and has been found to be effective to improve children's movement capabilities (Zhang, & Hongxin, 2018). The 'Get Active, Get Moving, Be Healthy!' tool consists of two parts, with each part including videos relating to each of the 12 FMS of the TGMD-2. In Part 1, each of the skill videos consists of:
    - a real-time demonstration of the skill performed by a young child, using the correct technique required by the TGMD-2
    - a slow-motion demonstration of the skill (zoomed in), while appropriate cue words/teaching points appear on screen
    - a repeated real-time demonstration of the skill performed correctly
    - a voiceover providing cues words/teaching points on how to perform of skill provided throughout the video.

This part of the tool could be used in numerous ways. It may be used in teacher training and coaching courses, as well as for professional development for teachers, coaches, early education providers and also parents, as it provides (i) visual demonstrations of how to correctly perform each skill (in real time), which will assist teachers in the recognition of correct/incorrect technique among students during attempts, (ii) cue words/teaching points which highlight the areas of technique that are necessary to demonstrate proficiency in the given skill and can be used as instructions/cue words when teaching the children how to perform the skill and (iii) a slow motion capture of the correct technique provides teachers with time to identify the specific criteria required for proficiency. It may also be used to show children a correct demonstration of each of the techniques as performed by another child (known as 'peer-modelling'). Peer-modelling has been found to be an effective strategy in several interventions aimed at increasing physical activity among children (Hardman, Horne, & Lowe, 2011; Horne, Hardman, Lowe, & Rowlands, 2009) and so this may also prove effective in promoting correct FMS technique.

In Part 2 of the tool, sample performances of the TGMD-2 assessment are provided. Each video consists of:

- a demonstration of the correct technique required by the TGMD-2 performed by the evaluator
- a familiarisation trial performed by Child 1 (young boy)
- test trial 1, which is then repeated in slow motion
- test trial 2, which is then repeated in slow motion
- a familiarisation trial performed by Child 2 (older boy)
- test trial 1, which is then repeated in slow motion
- test trial 2, which is then repeated in slow motion

In addition to the 12 videos, this part also consists of two documents; one which contains a blank scoring sheet which may be used to score the performances of the children and one which contains the correct scoring achieved by the children as scored by two experienced TGMD-2 performance raters.

This part of the tool also has many applications. It may be used in teacher training and coaching courses, as well as for professional development for teachers, coaches, early education providers as it (i) provides insight into how the TGMD-2 test may be administered, (ii) highlights some of the common errors typically observed among children and (iii) provides sample TGMD-2 performances of two primary school children (one young/one older) whose test trials may be either scored using the sample score sheet which can then be compared to the completed scoring sheet or viewed using the completed scoring sheet to aid understanding of the scoring protocol. The scores awarded across the performances can also be used in conjunction with the TGMD-2 to calculate different FMS outcome scores such as standard scores, GMQ, percentile scores and age equivalents. Furthermore, both parts of the tool may be used simultaneously, where Part 1 may serve as a reference for correct technique performed by a child, when attempting to score the test performances provided in Part 2.

It is suggested that Coaching Ireland and other national sporting bodies (e.g. Gaelic Athletic Association [GAA], Irish Rugby Football Union [IRFU], Football Association of Ireland [FAI]) should adopt this tool for use with athletes, parents and coaches to improve FMS knowledge and proficiency, and also to promote FMS training and continuous development among youth athletes nationwide.

- A final recommendation is that FMS-based workshops such as the Coaching Ireland Coaching Children Workshop Series (Coaching Ireland, n.d.) be delivered on a wider scale. The completion of such a course should be a requirement to be eligible to coach children within each sporting organisation, with a refresher session/course required every two years to update knowledge in the area of FMS. For teachers, it should be compulsory to complete a professional development workshops in the area of FMS such as that provided by the PDST (Professional Development Service for Teachers, 2018), every two years.

8.3 Limitations of the Current Research

The following limitations were identified in the current research.

- While this study involved both intervention (two medium-sized schools) and control (one large) schools, several notable differences existed between the school type and existing policies. The intervention schools were urban, single-sex schools (one boys and one girls), while the control school was a rural, mixed-sex school. However, it should be noted that all three schools were in close proximity (approximately 11km) to each other. The intervention schools had limited facilities with little yard space available and a shared sportshall. Therefore, on days on when the weather was unfavourable and the hall was unavailable, PE and/or Energizer-lessons and additional PA facilitated by the classroom teachers were confined to the classrooms with limited space available. In contrast, the control school had a large school hall (as well as a small hall), numerous large yards as well as an synthetic grass pitch and a grass pitch which were available for use throughout the school week. In the intervention schools, due to the confined space available, children were required to assemble indoors before the start of the school day in contrast to the control school who had permission to play in the school yards including the use of equipment. Furthermore, the girls school encountered additional limitations for PA in that they were not permitted to go outside during their first lunch break of the day nor were they permitted to run or use equipment (except skipping ropes) during the second lunch break. In contrast, the single-sex boys school and the mixed school cohorts participating in this study were permitted outside during all lunch breaks and had access to varied sports equipment (e.g. balls of various sizes etc.) providing greater opportunities to practice and develop FMS, particularly object-control skills. However, the single sex schools did have access to the local college facilities and a nearby large grass area (both within 10 minutes walking distance from the school), which they availed of several times throughout the year. It is recommended for future research that matched groups/schools are selected based on geographical location, sex, facilities, policies and school size. This would allow for a more accurate comparison of groups.
- This study involved only three primary schools located across a small geographical area in Cork, a region in south of Ireland. This may not be representative of the overall Irish primary school children population and therefore, meaningful

conclusions drawn from the current research may not be generalisable to the Irish child population. Furthermore, in each school, only a small sample were recruited (two class groups were for Year 1, while an additional two class groups were recruited for Year 2). Further investigation using a greater sample size across a wider age range and geographical area in Ireland would serve to identify the FMS proficiency levels among a larger, more representative sample of Irish primary school children and may also provide further support for the effectiveness of the FMS-based intervention at improving the proficiency levels of Irish primary school children.

- Due to limited accelerometer availability (relative to sample size), a sub-sample was randomly selected to whom accelerometers were distributed. Furthermore, due to poor wear time compliance, a further reduction in PA data collected was exhibited. Therefore, further analysis of the relationships between FMS, PA and PC is warranted among a larger (and wider age range) and more representative cohort of children. Also, rewards for those adhering to wear time requirements is suggested and shown to be effective in increasing wear time compliance (Sirard & Slater, 2009). Also, as the investigation between PC and PA levels conducted in this study was cross-sectional in design a longitudinal study investigating these relationships over time may provide further support and insight into these associations.

- A further limitation in terms of PA data collection was the fact that several children informed the researchers when returning their accelerometers that they removed their monitors when training/playing matches, despite instruction to wear them during all waking hours (except while bathing/showering/swimming). This may have been due to fear of damaging the monitor or discomfort experienced while competing. Also, as accelerometers may not be worn while swimming/swimming lessons, this PA may not be captured. For future collection of PA data, it is suggested that both accelerometers and PA diaries (in which parents/children record PA) are used to provide a more accurate measure of PA levels and that further encouragement to wear the accelerometer at all possible times is provided.

- FMS testing was conducted with each class group (up to 30 children) in the sportshall at the same time, with testing lasting approximately one hour. The hall was divided into four stations with the following skills tested at each station: (i) run, leap, hop, gallop, slide (ii) catch, throw, roll (iii) kick, strike (iv) dribble and jump. Groups of 5-8 children were allocated to each station. When skills were completed at a station, the groups simultaneously rotated clockwise until all 12 skills had been evaluated. While this protocol was effective and time-efficient, it is possible that children may have been distracted during the demonstration of a skill, due to the presence of other children in their group or due to the movement of other children and testers throughout the hall. Also, as children were required to wait for their own turn to attempt the skill, children may have forgotten the visual demonstration and may also have been influenced by the attempts to perform the skill made by their peers which preceded their own attempts. Children's concentration and attention levels and their ability to be patient while waiting their turn may also have influenced performances. Also, while testing in groups was more time efficient for testers, children were required to concentrate and perform throughout the hour, in contrast to 15-20 minutes if tested individually. Therefore, it is recommended for future research that FMS testing should be carried out individually with minimal external distraction to allow a most accurate measure of FMS proficiency.

- While FMS has been tested worldwide using the TGMD-2, it must be noted that it was developed in the United States and includes skills identified as culturally relevant among the US population. The skills and components required for proficiency in 11 of the 12 skills (with the exception of the strike) of the TGMD-2 can be applied in an Irish context. However, the strike technique which mirrors the fundamental technique required for a baseball strike is different to that required in hurling/camogie (a striking sport, one of the national games of Ireland), which requires a different hand-grip. Therefore, proficiency levels in the strike may be influenced by children's exposure to hurling/camogie. Therefore, it is suggested for future studies among an Irish population that children are awarded a '1' for the component requiring that the *'dominant hand grips bat above non-dominant hand',* (Ulrich, 2000) irrespective of actual hand-grip used to provide a more accurate measure of striking ability from an Irish perspective. In addition, the development of an additional or replacement test item for the strike skill is suggested to examine a hurling/camogie strike. Additionally, it is recommended that other culturally relevant test items (required/fundamental for participation in the national games of Ireland; hurling/camogie and Gaelic Football) also be developed (and validated) to be used in the examination of the FMS of Irish children. Some of these skills may include the hurling and football handpass, hurling ground strike and football punt kick.

- Another limitation of the current research included the fact that Energizer-led sessions replaced the allotted weekly PE time in the girls' school, while the boys' school also received a 30-minute weekly PE class delivered by the classroom teacher. This difference was due to individual school preferences and was not controllable by the *Project Spraoi* Research Team. However, as each teacher was permitted and encouraged to facilitate 20 minutes MVPA daily, this may not have influenced findings but nonetheless must be considered. For future research, it is recommended that all intervention groups received similar allocated PA time to maximise the quality of study design, findings and conclusions.

8.4 Recommendations for Future Research

A number of recommendations for future research are proposed.

- While it has been acknowledged that the multicomponent FMS-based intervention may not be feasible to be delivered across primary schools nationwide due to the additional cost of employing an Energizer, a step-back approach in which Energizers would implement a modification of the intervention in a large number of schools across several weeks (e.g. fortnightly/monthly visit per school) may prove both effective and feasible. The Energizer would continue to deliver Energizer lessons (during their fortnightly visit), provide resources (including lesson plans, manuals, homework manuals, posters etc.) and set up initiatives (e.g. PA charts, Stride for 5 competitions, etc.) within each school. This approach, implemented by Project Energize among New Zealand children, has been shown to be feasible and sustainable (Rush et al., 2016) and effective at improving FMS (Mitchell et al., 2013) as well as markers of health (Rush et al., 2012; Rush et al., 2016). Therefore, future research investigating the effectiveness of a step-back approach at improving FMS among an Irish child population is recommended.

- While this research adopted a whole-school approach with delivery of the intervention to all classes, testing was only conducted among 6-year-old and 10-year-old cohorts due to limited resources. Although these ages have been identified as significant developmental ages during the primary school years and an examination of these cohorts enabled international comparison with New Zealand (Graham et al., 2008), it is recommended that future research should assess the FMS levels across all primary school years (4-13 years) to provide an invaluable insight into the levels of FMS at each age as children progress through the primary schools. An assessment of FMS across a wide age range has been conducted among child populations worldwide including Belgium (Bardid et al., 2016) and Brazil (3- to 10-year-olds) (Spessato, Gabbard, Valentini et al., 2013). This would allow serve as reference data in the exploration of longitudinal trends in FMS among Irish primary school children.

- It is recommended for all future research using the TGMD-2 that testing should be conducted individually with children as opposed to in small groups. This may provide a more accurate measure of FMS proficiency as children's FMS performances will not be influenced by peers, external distractions and testing time for test completion would be minimized to ensure concentration and attention levels are maximised.

- It is apparent that a lack of teacher confidence, inadequate training and teacher competency are major barriers to the successful delivery of PE (Curtner-Smith, 1999; Decorby et al., 2005; Graham, 1991; Morgan & Bourke, 2005), which has negative implications for overall movement and FMS development. At present, Irish teachers (existing and trainee) receive limited PE training and professional development. While the PDST have launched the 'Move Well, Move Often' programme (Professional Development Service for Teachers, 2018) aimed at increasing FMS knowledge and ability to integrate FMS through the Irish PE curriculum, only a limited number of spaces are available to attend these seminars. Therefore, future recommendations for research include: (i) the assessment of FMS knowledge among teachers, (ii) the evaluation of teachers' confidence and competency in delivering FMS-based lessons and (iii) the effectiveness of extensive FMS teacher training on teachers' FMS knowledge and confidence and competency in delivering FMS-based PE lessons.

- While this intervention adopted the approaches found by Tompsett et al. (2017) to be most consistently associated with successful interventions, it is suggested that future research should include a greater focus on both parental and community involvement. In the current study, parental involvement was encouraged through homework manuals and several information sheets distributed to the children to bring home. The introduction of FMS homework manuals encouraged parents to engage in their children's FMS development. Each night, FMS homework completed was recorded in the manual by the either the children themselves or parents. However, it was not possible to ascertain if parents engaged in the homework with their children. Also as children often misplaced homework manuals, the accuracy and reliability of data relating to FMS practice conducted as well as parental involvement is unknown and has not been included. In this research, while several links were made with local institutions and members of local sports teams/clubs, community involvement was limited. Recent research provides evidence for the effectiveness of a 30-week community-based

FMS programme, 'Multimove' among children in Belgium (Bardid et al., 2017), while interventions among children incorporating both school and community involvement have been suggested to be very effective (Bleich, Segal, Wu, Wilson, & Wang, 2013; Shapiro, Arevalo, Tolentino, Machuca, & Applebaum, 2014). Therefore, future research may also include additional parental involvement such as parent evenings, parent-and-child fun PA/FMS evenings/events, information stands at the school to encourage greater parental involvement, as well as community involvement such as community PA/FMS, Activity Days as well as FMS training provided to coaches of various sports clubs/organisation and parents.

- While this study investigated the existing relationship between perceived FMS competence and both actual proficiency and MVPA with an existent relationship between PC and MVPA found, future research may investigate the relationship between these variables over time, as children progress across the primary school years and into middle childhood. With PA levels found to decrease with age and high dropout rates in sport, especially among girls, with half of girls dropping out of sport by the age of 14 (Bardon, 2018), the evaluation of this relationship over time may prove critical. For future collection of PA data, it is suggested that both accelerometers and PA diaries are used to provide a better measure of PA levels. It was found that numerous children removed their monitors when training/playing matches resulting in the failure to capture this PA. It is also suggested that wrist accelerometers, such as the GeneActiv wrist monitors, may be better suited for use among children with higher wear time compliance found for monitors worn on the wrist than the hip among children and also as many children found the belt uncomfortable (Fairclough et al., 2016). Also, while information obtained can be very useful, technical issues may arise and no information regarding the specific activity performed is provided (Sirard & Pate, 2001). However, while the use of self-report methods such as PA diaries may be used as an alternative as they are inexpensive and would provide this information, accurate data regarding intensity would not be obtainable and the ability/willingness of children/parents to accurately recall and report are also potential limitations in that regard (Ndahimana & Kim, 2017). Therefore, for future collection of PA data, it is suggested that both accelerometers (GeneActiv wrist device) and PA diaries (in which parents/children record PA) are used to provide a more accurate measure of PA levels.

- To date, there is no published data relating to the FMS proficiency levels among pre-school aged children in Ireland. Evidence from the current research has found less than satisfactory levels of FMS proficiency among primary school aged children, with poor FMS levels also found among Irish adolescents (Farmer et al., 2017; Lester et al., 2017; O'Brien et al., 2016). However, as children have the potential to master FMS by the age of seven (Gallahue et al., 2012), it is essential that early interventions aimed at improving FMS are implemented during the early years, including the pre-school years. The TGMD-2 has been shown to be a valid and reliable assessment tool among children of pre-school age (Ulrich, 2000). Therefore, future research should investigate the FMS proficiency levels among pre-school children in Ireland, which may aid in the development and planning of appropriate interventions, activities and lessons to improve FMS.

- While this study assessed FMS proficiency across two academic years, future longitudinal research over a longer time period (e.g. five years, across the primary schools years, into middle childhood) is recommended to track FMS proficiency as children grow older. In addition, an assessment of the FMS proficiency among the cohort assessed in this study across the academic years following the intervention (follow-up study) may evaluate the long-term impact of the FMS intervention.

8.5 Conclusion

As FMS proficiency among primary school children in Ireland (a cohort of 6- and 10-year-olds) as well as worldwide (4- to 13- year-olds) are less than satisfactory, ranging from *below average* to *average*, there is large potential for FMS development among primary school children.

As children have the potential to master FMS by age seven (Gallahue et al., 2012), early interventions aimed at improving actual FMS are warranted as FMS facilitate sport and PA participation and are associated with numerous health benefits. The current research revealed that a PA-based intervention was not more effective at improving the FMS proficiency of primary school children than the existing Irish PE curriculum. However, the evaluation of the multicomponent FMS intervention resulted in large significant improvements in locomotor, object-control and overall FMS proficiency, relative to the control group. Therefore, it is evident that FMS are not acquired naturally (Barnett, Stodden et al., 2016; Clark, 2005; Pang & Fong, 2009) but rather, require quality instruction, practice and feedback.

Given the existing high levels of overweight/obesity and physical inactivity based on international comparisons with Ireland predicted to be the fattest of 53 nations by 2030 (Tremblay, 2014; Woods et al., 2014), the implementation of an FMS-based intervention delivered across primary schools nationwide has the potential to improve FMS proficiency among Irish primary school children. Furthermore, the findings of the current research, as well as the resources developed, should be used to guide national PA, health and educational policy makers and aid teacher training colleges, national coaching bodies to increase FMS proficiency levels among Irish children. These approaches may aid and assist FMS development during childhood, thus promoting PA and a healthy weight status, which may help combat the rise in obesity and physical inactivity among Irish children.

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Appendix A: Publications

A.1 List of Published/Accepted Articles:

1. Bolger, L. E., Bolger, L. A., O' Neill, C., Coughlan, E., O'Brien, W., Lacey, S., & Burns, C. (2018). Age and sex differences in fundamental movement skills among a cohort of Irish school children. *Journal of Motor Learning and Development*, *6*(1), 81-100. https://doi.org/10.1123/jmld.2017-0003

2. Bolger, L. E., Bolger, L. A., O' Neill, C., Coughlan, E., O'Brien, W., Lacey, S., & Burns, C. (in press). Accuracy of children's perceived skill competence and its association with physical activity. *Journal of Physical Activity and Health.*

3. Bolger, L. E., Bolger, L. A., O' Neill, C., Coughlan, E., O'Brien, W., Lacey, S., & Burns, C. (in press). The effectiveness of two interventions on fundamental movement skill proficiency among a cohort of Irish primary school children. *Journal of Motor Learning and Development.*

A.2 Conference Papers

(Oral Presentation at the 22nd Annual Congress of the European College of Sport Science, Essen, Germany, 5-8th July 2017)

The effectiveness of a school-based motor development intervention on fundamental movement skill proficiency and markers of health among Irish children

Bolger, L.A., Bolger, L.E., O' Neill, C., Coughlan, E., Burns, C.

Cork Institute of Technology (Ireland)

Introduction

Fundamental movement skill (FMS) proficiency among children worldwide is low. There is a paucity of related research in existence among European children, with no recorded data in an Irish context. Health data of Irish children has reported that 25% are unfit, overweight/obese, and have high blood pressure (Woods *et al.* 2010). The purpose of the current study was to assess the effectiveness of a motor development intervention on FMS proficiency and markers of health among Irish children.

Methods

Children (N=446, mean age: 8.5±2.07 years, range: 5.2-12.2 years) from 2 intervention and 1 control school were selected to participate in the study. FMS proficiency was evaluated using the Test of Gross Motor Development-2 (Ulrich 2000), with 6 locomotor (LOCO) and 6 object-control (OC) skills assessed. Selected markers of health were BMI, 550m run/walk time and physical activity (PA) measured via accelerometry. The intervention was delivered across one academic year and consisted of 2 X 25 minute FMS-specific sessions per week.

Results

The intervention (INT) group significantly increased TOTAL FMS (67.5±7.21 to 74.5±5.45, $p<0.01$), LOCO (40.8±3.97 to 44.2±3.15, $p<0.01$) and OC scores (26.9±4.98 to 30.3±3.85, $p<0.01$). In contrast, the control (CON) group showed significant decreases in TOTAL FMS (68.8 ± 6.21 to 67.1±7.12, $p<0.01$) and LOCO scores (40.8±3.80 to 39.8±3.95, $p<0.01$), with no difference evident in OC ($p>0.05$). The INT group significantly improved in 10 of the 12 FMS tests, while the CON group improved in only 3 ($p<0.05$).

Markers of health analysis found a significant decrease in the BMI of the INT group (mean change: -0.6±1.46 kg/m^2, $p<0.01$), while a significant increase in BMI was observed in the CON group (mean change: 0.2±0.68, $p<0.05$). There were significant improvements in 550m run/walk times among both the INT and CON groups (mean change: INT-19.6±22.61 secs v CON -12.5±21.26 secs, $p<0.05$ for both), with a significantly greater improvement in the INT group ($p<0.01$). Both groups significantly increased total PA (mean change: INT 21.7± 38.82 minutes v CON 41.9±48.48 minutes, ($p<0.05$), with no difference between the mean changes ($p>0.05$).

Discussion

The implementation of a school-based motor development intervention has the potential to improve FMS proficiency and markers of health among Irish children.

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The effectiveness of a school-based motor development intervention on fundamental movement skill proficiency and markers of health among Irish children

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Introduction: Fundamental movement skill (FMS) proficiency among children worldwide is low. There is a paucity of related research in existence among European children, with no recorded data in an Irish context. Health data of Irish children has reported that 25% are unfit, overweight/obese, and have high blood pressure (Woods *et al* 2010). The purpose of the current study was to assess the effectiveness of a motor development intervention on FMS proficiency and markers of health among Irish children.

Methods: Children (N=446, mean age: 8.5±2.07 years, range: 5.2-12.2 years) from 2 intervention and 1 control school were selected to participate in the study. FMS proficiency was evaluated using the Test of Gross Motor Development-2 (Ulrich 2000), with 6 locomotor (LOCO) and 6 object-control (OC) skills assessed. Selected markers of health were BMI, 550m run/walk time and physical activity (PA) measured via accelerometry. The intervention was delivered across one academic year and consisted of 2 X 25 minute FMS-specific sessions per week.

Results: The intervention (INT) group significantly increased TOTAL FMS (67.5±7.21 to 74.5±5.45, $p<0.01$), LOCO (40.8±3.97 to 44.2±3.15, $p<0.01$) and OC scores (26.9±4.98 to 30.3±3.85, $p<0.01$). In contrast, the control (CON) group showed significant decreases in TOTAL FMS (68.8 ± 6.21 to 67.1±7.12, $p<0.01$) and LOCO scores (40.8±3.80 to 39.8±3.95, $p<0.01$), with no difference evident in OC ($p>0.05$). The INT group significantly improved in 10 of the 12 FMS tests, while the CON group improved in only 3 ($p<0.05$).

Markers of health analysis found a significant decrease in the BMI of the INT group (mean change: -0.6±1.46 kg/m2, $p<0.01$), while a significant increase in BMI was observed in the CON group (mean change: 0.2±0.68, $p<0.05$). There were significant improvements in 550m run/walk times among both the INT and CON groups (mean change: INT-19.6±22.61 secs v CON -12.5±21.26 secs, $p<0.05$ for both), with a significantly greater improvement in the INT group ($p<0.01$). Both groups significantly increased total PA (mean change: INT 21.7± 38.82 minutes v CON 41.9±48.48 minutes, ($p<0.05$), with no difference between the mean changes ($p>0.05$).

Conclusion(s): The implementation of a school-based motor development intervention has the potential to improve FMS proficiency and markers of health among Irish children.

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The relationship between fundamental movement skill proficiency and health markers among Irish primary school children

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Introduction

Fundamental movement skills (FMS) are basic movements that facilitate physical activity participation and sports performance (Gallahue & Ozmun, 2006). Low FMS proficiency is likely to act as barrier to many forms of organised and non-organised physical activity (Cliff *et al.*, 2012). Low FMS levels have been reported among children worldwide. Levels among Irish primary school children have been reported to be lower than those their counterparts in other countries (Bolger *et al.*, 2015). Children with higher FMS have been reported to have greater aerobic fitness and are less likely to be overweight (Lubans *et al.*, 2010). Research has also shown that there is an inverse relationship between FMS competency and body composition (Slotte *et al.*, 2015) and that FMS proficiency is a determinant of physical activity levels.

Methods

Data presented is extracted from baseline measures of *Project Spraoi*, a primary school-based physical activity and nutrition intervention in Cork. Participants (N=203) were senior infants (n=102) and fourth class (n=101) students from 3 primary schools in the region. FMS testing was conducted across 4 days using the Test of Gross Motor Development-2 (TGMD-2) (Ulrich, 1985) with 12 basic movement skills (6 locomotor and 6 object-control) analysed. Performance was recorded on video cameras, uploaded to a laptop and analysed retrospectively by 2 evaluators using the TGMD-2 scoring protocol. Inter-rater agreement of 85% and intra-rater reliability of 95% was reached across all skills. Locomotor (a sum of the scores from the 6 locomotor skills), object control (a sum of the scores from the object control skills) and total FMS (a sum of the locomotor and object control scores) scores were calculated.

Health markers included in the analyses were body mass index (BMI) (classified into categories using IOTF reference cut points), waist circumference (WC) and resting blood pressure (BP). Cardiovascular fitness (CVF) was assessed using a 550m run/walk test. Levels of habitual physical activity was assessed using 7 day accelerometer protocol with a subsample of participants (n = 27). Spearman rho was used to assess the relationship between FMS and markers of health.

Results

Overall, there was a clear trend between CVF and FMS. A negative correlation was found, indicating faster run times were significantly correlated with higher FMS scores. Among the senior infants, CVF was significantly correlated with object control (-0.393, $p < 0.0005$) and total FMS (-0.419, $p < 0.0005$) while among 4th class students, CVF was correlated with locomotor (-0.452, $p < 0.0005$), OC (-0.533, $p < 0.0005$) and total FMS (-0.311, $p < 0.0005$). Heart rate was inversely correlated with these FMS scores among the sample ($p < 0.0005$), with large correlations between heart rate and locomotor (-0.288, $p < 0.0005$), OC (-0.225, $p = 0.001$) and total FMS (-0.307, $p < 0.0005$). There were no significant correlations between FMS scores and the remaining health markers (BMI category, waist circumference, blood pressure, physical activity level).

Discussion and Conclusion

Children with higher FMS scores had lower heart rates and higher fitness levels, which suggests that developing FMS among children is important for CVF. Research has found that FMS interventions can improve fitness among primary school children (Cohen *et al.*, 2014). Improving children's actual FMS competence may improve their perceived competence which is an important factor for subsequent physical activity and fitness (Barnett *et al.*, 2008). While no relationship was found between FMS scores and BMI, waist circumference, blood pressure and physical activity level among children of this young age, the relationship may become apparent later in life (through adolescence and adulthood).

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Fundamental movement skill proficiency across gender and age among Irish primary school children

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Introduction
Fundamental movement skills (FMS) are basic movements that facilitate physical activity participation and sports performance. Low FMS levels have been reported among children worldwide with evidence of gender and age-related differences featuring prominently. While it has been reported that FMS proficiency among post-primary school children is low in Ireland, there is a paucity of data relating to respective levels of their primary school counterparts. The purpose of this study is to evaluate FMS proficiency of Irish primary school children and examine and quantify any gender and age-related differences that exist.

Methods
Data presented is extracted from baseline measures of *Project Spraoi*, a primary school-based physical activity and nutrition intervention in Cork. Participants (N=205) were senior infants (n=103) and fourth class (n=102) students from 3 primary schools in the region. FMS testing was conducted across 4 days using the Test of Gross Motor Development-2 (TGMD-2) (Ulrich, 1985) with 12 basic movement skills (6 locomotor and 6 object-control) analysed. Performance was recorded on video cameras, uploaded to a laptop and analysed retrospectively by 2 evaluators using the TGMD-2 scoring protocol. Inter-rater agreement of 85% and intra-rater reliability of 95% was reached across all skills. FMS mastery levels were achieved when all components of a skill were present. Total FMS score, the sum of the components present for all 12 skills across both trials, was also calculated. Independent sample t-tests were used to assess gender and age-related differences.

Results
Levels of FMS mastery were low with no child achieving mastery across all 12 FMS. Mean scores for mastery in locomotor skills and object control proficiency were 45±23% (range 12-78) and 27±18% (range 7-60) respectively. On analysis of total FMS scores, boys scored significantly higher than girls (75.8 vs 71.8%: p<0.01) and older children scored significantly higher than younger children (80.4 vs 67.6%: p<0.001).

Discussion
FMS proficiency levels of Irish children were lower than those of Australian primary school children (Mitchell *et al.* 2011) for all skills except the kick. The superior level of mastery among Australian children may be due to the greater emphasis on physical literacy in the Australian primary school PE curriculum while the greater kicking ability of Irish children may result from the cultural emphasis on kicking-based sports (i.e. Gaelic football and soccer). Gender differences reported concur with recent international findings in the field while age-related differences may be rationalised by the natural process of growth and maturation.

Conclusion
FMS mastery was found to be low among Irish primary school children, with higher scores attained in locomotor skills relative to object control skills. Superior FMS proficiency was demonstrated by boys while older children demonstrated greater FMS mastery than the

younger cohort. These differences may be addressed with appropriate instruction, feedback and practice. Based on the findings, strategies to improve FMS of primary school children are necessary in Ireland.

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A.3 Conference Poster

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Title: *"I can walk, I can talk but… I just can't JUMP?"* – Movement skill proficiency amongst primary school children in Ireland

Names:

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Purpose:

Evidence now suggests that activity programmes for youth ought to provide intense instruction towards basic movement skills needed to enjoy a variety of physical activities (O'Brien, Issartel and Belton, 2013; Belton *et al.*, 2014). Fundamental Movement Skills (FMS) are basic observable patterns of behaviour present from childhood to adulthood. With a noticeable absence in Irish literature relating to childhood movement patterns, the present study assessed the performance of twelve FMS amongst 5 to 11 year old children.

Methods:

Baseline data were collected in October 2014 as part of a larger longitudinal study (*Project Spraoi*), evaluating the effectiveness of a prescribed physical activity intervention for children. Participants included children (N=218; 7.95 ± 2.00 years) from three primary schools in a specific geographic area of Co. Cork, Ireland. The following 12 FMS were assessed in a physical education hall using reliable instrument protocol; run, gallop, slide, hop, leap, horizontal jump, kick, catch, overhand throw, strike, underhand roll and stationary dribble. Each of the 12 FMS were assessed in conjunction with the behavioural components from the established Test of Gross Motor Development-2 (TGMD-2).

Results:

Of the 205 participants, not one possessed complete mastery level across the twelve object related and locomotor movement skills. There was a significant difference in the overall mean composite FMS score (object control and locomotor) between gender, with boys scoring higher ($p<0.05$). There were marked differences in the number of participants who failed to obtain mastery level across the range of the twelve FMS (e.g. Underhand Roll 93%, Run 22%) and their associated behavioural components.

Conclusions

It is alarming that primary school children do not display proficiency across twelve basic movement patterns. This finding indicates that older children, particularly those aged 9 to 11 years of age may have a difficult time in making the successful transition towards more advanced skills within the sport specific stage. Implications from this study potentially indicate that targeting the weakest skill components during physical education and outside of school hours may prove a valuable strategy in increasing the current FMS levels and the subsequent PA levels amongst Irish primary school children.