Moving Well-Being Well: Evaluation and development of the fundamental movement skills in Irish primary school children through a physical literacy lens

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A thesis submitted for the award of Doctor of Philosophy (PhD)

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Submitted to Dublin City University, January 7th, 2020

Authors Declaration:

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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Acknowledgements

I would like to thank the following people who helped in various ways during the completion of my thesis:

To my supervisors, Dr Johann Issartel, Dr Sarahjane Belton, & Prof Noel O'Connor, thank you for your patience, guidance and encouragement. Noel, thank you for backing me from the start and all the advice along the way. Sarahjane, thank you for the constant support and for driving me to be better. To Johann, simply thank you for taking a chance on me, it has been quite the journey, thank you for everything.

To all the post grads /post docs who are in (or have been) in the 'PARTY' lab. Thank you for all the support through the years.

To Cameron, my partner in crime throughout this PhD journey. We made it without killing each other, who would have thought it. Thanks for everything man.

To all the schools, children and parents who participated in the study.

To all at the School of Health and human Performance for the help and support.

To all in the Insight Centre for Data Analytics. To the two Deirdre's, Karen, Frances, Aoibheann and Breda – thank you for keeping me on the straight and narrow.

To both Dublin GAA and the GAA's Games Development and Research department for working together and backing the project.

To all in the wider GAA community, particularly Leinster GAA, who helped along the way, whether it be through introduction to schools, assistance with testing or any of the many tasks we asked of you.

Finally, a special thanks my family, thank you for your unconditional support and encouragement. Big thanks to Dad for his unerring proof reading.

Funding Sources:
This research was funded by the Insight centre for Data Analytics, and co-funded by the GAA's Games Development and Research department and Dublin GAA.
Research funded by Science Foundation Ireland under grant numbers SFI/12/RC/2289 and SFI/12/RC/2289-P2

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Abstract

Title: Moving Well-Being Well: Evaluation and development of fundamental movement skills in Irish primary school children through a physical literacy lens

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Just 19% of children in Ireland get the recommended 60-minutes of moderate-vigorous physical activity per day, therefore culturally relevant initiatives aimed at increasing physical activity (PA) are urgently needed. Physical Literacy (PL) is purported to be a pathway towards Physical Activity (PA) and health, with Fundamental Movement Skills (FMS) being a core component of the accepted PL model. Another factor linked with FMS is Health-Related Fitness (HRF), and HRF has shown positive associations with health. Phase One of this study comprised of a nationwide assessment of a broad range of FMS, and all the HRF components across primary school-children (n=2098, 47% girls, age 5-12 years) in order to ascertain a true reflection of Irish children's FMS and HRF status.

Irish children demonstrated low levels of FMS mastery (25.2% - 56.7%), with boys significantly outperforming girls in object control skills ($p<0.001$, eta squared = 0.08 – 0.13). Improvements in ability were evident with age, with FMS proficiency increasing significantly up to ten years of age, after which a plateau in proficiency occurred. Age-related differences in the FMS-HRF relationship were also found, with a positive association between FMS and HRF that strengthened with age (β = -0.189 – 0.393).

The next phase assessed the efficacy of a unique and novel exploratory trial aimed at increasing FMS in Irish primary school children (n = 417, 52% female, age = 7.6 ±0.66). Multilevel analyses revealed significant interaction effects across time for the intervention group ($p<0.001$, $d = 1.5$).

Overall, findings highlight low levels of FMS proficiency in Irish children, and the need for a strong focus on FMS with young children, through a PL lens. These findings suggest that an intervention, such as outlined in this document, could help increase PA levels, PL in general, and in turn, increase the positive health benefits associated with PA.

Chapter 1: Introduction to Thesis

1.1 Publications:

Published:

Moving Well-Being Well: Investigating the maturation of fundamental movement skill proficiency across sex in Irish children aged five to twelve.

Journal of Sports Science - accepted 16th July 2019, published online 5th August 2019.

Authors: Stephen Behan, Sarahjane Belton, Cameron Peers, Noel E O'Connor, & Johann Issartel

Under Review:

Evolving dynamics between fundamental movement skills and health related fitness components in children

European Journal of Sports Science - submitted June 2019. Manuscript ID TEJS-2019-0750.

Now under second round of review

Authors: Stephen Behan, Sarahjane Belton, Cameron Peers, Noel E O'Connor, & Johann Issartel

Exploring the effectiveness of the Moving Well-Being Well intervention on primary school children's motor competence.

Journal of Motor Behaviour - submitted September 2019.

Authors: Stephen Behan, Sarahjane Belton, Cameron Peers, Andrew McCarren, Noel E O'Connor, & Johann Issartel

Development of a refraction framework to underpin design of the Moving Well-Being Well physical literacy intervention

International Journal of Behavioural Nutrition and Physical Activity – submitted September 2019

Authors: Johann Issartel, Jamie McGann, Sarahjane Belton, Cameron Peers, Noel E O'Connor, & Stephen Behan.

Oral Presentations:

Moving Well-Being Well: Physical literacy towards health

Health Promotion Ireland Conference – June 2018, NUIG, Galway, Ireland.

Moving Well-Being Well: Getting Ireland's children moving

Children's Research Network PhD Symposium – August 2018, UCD, Dublin, Ireland.

Getting Irelands Children Moving – insights into Irish children's physical literacy

Insight Centre Student Conference – September 2018, UCD, Galway, Ireland.

Moving Well-Being Well: An intervention aimed at increasing fundamental movement skills in Irish primary school children, while also increasing teacher confidence in delivering physical activity based lessons.

International Society for Physical Activity and Health (ISPAH), October 2018, London, UK.

Moving Well-Being Well: An overview of Irish children's physical literacy

Physical Education and Physical Activity and Youth Sport (PEPAYS) – November 2018, University of Limerick, Ireland.

Moving Well-Being Well: How digital interventions can help improve physical literacy in Irish children

Children's Research Network Annual Conference, December 2018, Dublin, Ireland.

Moving Well-Being Well: Exploring components of physical literacy in Irish children

International Physical Literacy Conference (IPLC), May 2019, Winnipeg, Canada.

A physical literacy approach to coaching children

iCoach Kids Conference – June 2019, Limerick, Ireland.

Poster Presentations:

Moving Well-Being Well: Fundamental movement skills in Irish primary school children
Physical Education and Physical Activity and Youth Sport (PEPAYS) – September 2017, University of Limerick, Ireland.

Moving Well-Being Well – Preliminary findings for Irelands physical literacy
Insight Centre Student Conference – September 2017, NUIG, Galway, Ireland.

Getting Irelands Children Moving – Insights into Irish children's physical literacy
Insight Centre Student Conference – September 2018, UCD, Galway, Ireland.

Getting Irelands children moving: Examining fundamental movement skills in Irish school children as a key component of physical literacy
North American Society for Psychology in Sport and Physical Activity (NASPSPA) – June 2018, Denver, USA.

Moving Well-Being Well: An intervention aimed at increasing fundamental movement skills in Irish primary school children, while also increasing teacher confidence in delivering physical activity based lessons.
International Society for Physical Activity and Health (ISPAH), October 2018, London, UK.

Moving Well-Being Well: Exploring components of physical literacy in Irish children
International Physical Literacy Conference (IPLC), May 2019, Winnipeg, Canada.

1.2 Introduction

In a previous role, I worked as a Games Promotions Officer for the Gaelic Athletic Association (GAA). The GAA is Ireland's largest sporting organisation and promotes indigenous Gaelic games such as Gaelic football, hurling, camogie, handball and rounders. As part of this role I coached these games in primary schools across Dublin, and to my shock I regularly came across children who had no interest in partaking, not just in Gaelic games, but in any form of physical activity (PA). PA is defined as "*any bodily movement produced by the skeletal muscles that results in a substantial increase over resting expenditure*" (Caspersen, Powell, & Christenson, 1985). Guidelines from the Irish government's Department of Health and Children (2009) stats that all children and young people should get at least one hour a day of moderate to vigorous intensity physical activity (MVPA). Results from the Children's Sport Participation and Physical Activity (CSPPA) study recently released showed that only 17% of primary school going age children and 10% of adolescents met these requirements (Woods et al., 2018).

This low level of PA among youth is not just the case in Ireland, with worldwide reports that 80.3% of 13-15 year olds are not meeting the PA guidelines (Hallal et al., 2012). According to the World Health Organisation (WHO), this physical inactivity is listed in the top five risk factors for mortality (WHO, 2009). While it is listed as a risk factor, physical inactivity is also associated with three of the four remaining highest risk factors, namely high blood pressure, high blood glucose, and obesity (WHO, 2009). Research also shows us that those who develop these risk factors as children are far more likely to develop poor health outcomes as adults (Raitakari et al., 2003). In contrast, PA is linked with a host of positive health benefits, such as reduced risk of cardiovascular disease, decreased risk of type II diabetes, increased bone health, reduced risk of obesity, as well as mental health benefits (Lubans et al., 2016; Ortega, Ruiz, Castillo, & Sjöström, 2008). In light of the many benefits, it seems crucial that every effort is made to ensure children are physically active. In order to do this effectively, we must investigate the factors which motivate children to engage in PA.

Children must first and foremost be afforded the opportunity to be active. Socioeconomic status can play a role, with those in areas classed as disadvantaged arguing that they encounter barriers to being physically active (Chinn, White, Harland, Drinkwater, & Raybould, 1999). Family can also play a key role in determining activity levels, with children often influenced in enrolment in sport and other activities (Sallis, Prochaska, & Taylor, 2000). Looking at the results from the CSPPA report again, it advises that support from family and teachers are important factors for increasing PA participation (Woods et al., 2018). In light of this, it seems important to consider the whole environment surrounding the child, in order to get a deeper knowledge of what drives them to be active. Understanding what motivates children to take part in PA could be key to tackling the rising levels of physical inactivity. One model which seeks to understand children's motivation towards PA is the concept of physical literacy (PL), and a growing body of research is investigating the importance of PL towards health and PA (Cairney, Dudley, Kwan, Bulten, & Kriellaars, 2019; Tremblay et al., 2018).

Physical literacy is defined as "*the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life*" (International Physical Literacy Association, 2017). When talking about PL in the context of children being active, the first consideration is whether a child has the physical competence to move well or perform the skill required in a given activity. If a child is confident in their capacity to move in various different environments, then their motivation to engage in activities should also increase (Whitehead, 2013). Additionally, if a child also has the knowledge of what is required to move well, and understands why it is important, then this also feeds into their motivation and confidence to be active (Whitehead, 2013). Examining how these various components interact could be the key to understand what motivates children to be active (Cairney et al., 2019). There are however issues in measuring PL, with researchers struggling to reach consensus about how PL should be assessed (Edwards, Bryant, Keegan, Morgan, & Jones, 2017). It is worth mentioning at this point that this study is part of a larger research project called Moving Well-Being Well. A primary aim of this wider project is to attempt to assess PL in Irish children. While the afore mentioned problems in measuring PL are still present, the research team believe that this will be the first study of its kind to measure all elements of PL across a wide range of ages in a large sample of children. All assessments employed are proven, age appropriate validated measures. It is hoped that this will help give us a deeper understanding of the intricacies of how the components of PL interact and add to the developing research in the PL landscape. A colleague of mine is also on his PhD journey alongside me, examining the motivation and confidence components of PL. As we have already seen, motivation and confidence are purported to impact PA participation. To compliment my colleagues work, my research will focus on the physical competence component of PL. The physical competence component is accepted as a key driver towards PA, specifically when talking about the ability to perform basic motor skills, commonly referred to as the fundamental movement skills (FMS) (Logan, Ross, Chee, Stodden, & Robinson, 2018).

FMS are the basic building blocks of more complex movements that are needed to participate in PA or sport (Logan et al., 2018). FMS is made up of locomotor skills (e.g. running, skipping), object control skills (e.g. kicking and throwing), and stability skills (e.g. balance). While children have the potential to master these skills by six years of age (Gallahue & Ozmun, 2006), it is widely accepted that all children should master these basic skills by the age of ten (Hardy, King, Farrell, Macniven, & Howlett, 2010a). Many are under the impression that these skills are developed naturally, but these skills must be taught and developed (Clark, 2007; Haywood & Getchell, 2019; Cools, Martelaer, Samaey, & Andries., 2009; Stodden, Goodway, Langendorfer, Roberton, Rudisill, Garcia, C., & Garcia, L., 2008). As children gain mastery of the FMS, they begin to link and refine these skills to produce sports specific skills (McKenzie & Lounsbery, 2009; Robinson et al., 2015a). Failure to master the FMS can lead to physical inactivity, as if a child does not have proficiency in the skills required to take part in an activity, they are likely to drop out of that activity (Seefeldt, 1980; Stodden, True, Langendorfer, & Gao, 2013). The opposite, however, is also true, with numerous studies linking FMS proficiency with increased PA (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Jaakkola, Yli-Piipari, Huotari, Watt, & Liukkonen, 2016; Lubans, Morgan, Cliff, Barnett, & Okely, 2010). Many now believe that mastering the FMS early in childhood leads to increased participation in PA during the teenage years (Barnett et al., 2009a; Hardy et al., 2013; Jaakkola et al., 2016; Stodden et al., 2008). Others maintain that the relationship between FMS and PA is part of a wider construct, with FMS, PA, perceived movement competence, and health related fitness (HRF) all interacting towards positive or negative trajectories of health (Stodden et al., 2008).

HRF is made up of several components: cardiovascular endurance (CVE), muscular strength, muscular endurance, flexibility and body composition (Caspersen et al., 1985). HRF has been recognised as a powerful indicator of health (Pate, Oria, & Pillsbury, 2012). Similar to PA, there is substantial evidence showing HRF to have a positive relationship with mental health, obesity risk, bone health and risk of cardiovascular disease (Kvaavik, Klepp, Tell, Meyer, & Batty, 2009;

Ortega et al., 2008). Stodden and colleagues (2014) maintain that HRF and FMS have a dynamic relationship, and that their interaction can influence children's participation in PA. The relationship between the two has been widely researched, with a positive relationship between FMS and most of the HRF components reported, and findings highlighting an inverse relationship with body composition (Cattuzzo et al., 2016; Lubans et al., 2010). Research in Finland has shown indirect pathways from FMS to PA through HRF, and also indirect pathways from HRF to PA through FMS (Jaakkola et al., 2019). This would suggest that the relationship between FMS and HRF is a reciprocal one and implies that FMS can have a major role in improving HRF. Given the previously discussed health benefits to improved HRF levels (Caspersen et al., 1985), and the aforementioned links between FMS and PA (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Jaakkola, Yli-Piipari, Huotari, Watt, & Liukkonen, 2016; Lubans, Morgan, Cliff, Barnett, & Okely, 2010), it seems clear that efforts to improve FMS in Irish children should be undertaken. The school setting provides an ideal opportunity to do this (McKenzie & Lounsbery, 2009).

The school environment is thought to be a particularly salient one to develop FMS, with the physical education (PE) lessons touted as an ideal opportunity to teach FMS (McKenzie & Lounsbery, 2009). The Irish primary PE curriculum does have a focus on motor development (Department of Education and Skills, 1999), but one has to wonder if this is adhered to in the school setting, with several studies showing Irish children with low levels of FMS mastery (Bolger et al., 2018; Farmer, Belton, & O'Brien, 2017; Kelly, O'Connor, Harrison, & Ní Chéilleachair, 2018). This poor competency is not just an Irish trend, with several countries reporting low FMS proficiency levels in children (Bardid et al., 2016; Lubans et al., 2010; Mukherjee, Ting Jamie, & Fong, 2017; van Beurden, Zask, Barnett, & Dietrich, 2002). Interventions targeting FMS have proven to be successful in the primary school setting (Cohen, Morgan, Plotnikoff, Barnett, & Lubans, 2015; McKenzie, Sallis, & Rosengard, 2009; Rush et al., 2016; Van Beurden et al., 2003), so it seems prudent that FMS interventions for the Irish primary school population be explored.

While school based interventions have been shown to be effective in increasing FMS in children, those which utilise multiple components and are underpinned with relevant theoretical frameworks have proven to be the most successful (Craig et al., 2008; Kriemler et al., 2011; Stull, Snyder, & Demark-Wahnefried, 2007). Programmes which contain components such as: family involvement (Belton, O'Brien, Meegan, Woods, & Issartel, 2014a), community involvement (Acker et al., 2011), active classrooms (Martin & Murtagh, 2017), and teacher training (McKenzie, Sallis, & Rosengard, 2009) are among those which have been seen to have a significant impact on the participants FMS. Understanding the effective components from interventions that have been proven successful will help inform future intervention design and development.

This thesis aims to first gain an accurate picture of the FMS proficiency levels in Irish primary school children. While there have been some studies that examine FMS in Irish children, these are limited to small sample sizes and a localised population (Bolger et al., 2018; Farmer et al., 2017; Kelly et al., 2018). A representative sample across the entire primary school cohort, taking socioeconomic, gender and school ethos into consideration, would give a true reflection of the FMS levels in Irish children and physical literacy levels in general.

There is a need to investigate correlates of FMS and PA such as HRF. While this has been done several times, some have used just one component of HRF as a proxy (Cattuzzo et al., 2016) and others may have used a composite HRF score but have only used a narrow range of FMS measures (Stodden, Goodway, & Langendorfer, 2014). Given the positive health benefits associated with HRF (Cattuzzo et al., 2016), the second aim of this study is to investigate the relationship between the entire FMS range and each HRF component in Irish children. Once a clear picture of the landscape in Ireland has been established, an evidence based intervention can be designed that is culturally relevant to Irish children. The final aim of this thesis is to evaluate the effectiveness of the Moving Well-Being Well exploratory trial in improving FMS proficiency in an Irish primary school setting.

1.3 Philosophical Position

When considering the methods and findings of the studies described in this thesis, it is important to acknowledge my own experiences and philosophical position. Stemming from ontology (what exists for people to know about) and epistemology (how knowledge is created and what is possible to know) are philosophical perspectives (generalised views of the world), which forms beliefs and drive actions (Moon & Blackman, 2014). As previously mentioned, I spent a good deal of time in primary schools coaching GAA sports working as a Games Promotion Officer for Dublin GAA, with a purely positivist approach. As I continued to develop throughout the PhD project, my knowledge of the underpinning philosophies of physical literacy (monism, existentialism and phenomenology) has continued to develop. Looking at PL as a concept, the literature will show that there are many different ways of interpreting and undertaking research (Edwards et al., 2018), and that no single stance can give a complete understanding (Poucher, Tamminen, Caron, & Sweet, 2019). This study, however, primarily aims to view fundamental movement skills through the lens of PL, and primarily focuses on the physical competence component of PL. The subsequent interpretations made throughout this PhD will have been influenced by my own experiences and understandings. In this regard, I view myself as a positivist researcher; I believe that studies which rely on scientific evidence, such as experiments and statistics, reveal a true nature of how society operates. In an effort to ensure the coherence of a thesis, the researchers should demonstrate that the approach they have chosen is the most suitable to answer their research question in line with their philosophical position (Poucher et al., 2019). To this end, the approaches laid out in this thesis are all based on well-established, validated and robust methodologies. Research should, in my opinion, generate meaningful impact, and building on previous empirical evidence is, in my view, the best way to do this.

1.3 Aims and objectives of the study

Primary aims of research:

1. To conduct a nationwide evaluation of Irish primary school children's fundamental movement skills proficiency (Chapter 3).

2. To examine the relationship between fundamental movement skills and health related fitness components in Irish primary school children (Chapter 4).

3. To assess the efficacy of the Moving Well-Being Well intervention on improving the fundamental movement skills of Irish primary school children in an exploratory trial (Chapter 5).

Secondary Objectives:

1. To assess gender differences in Irish children's fundamental movement skill proficiency (Chapter 3).

2. To examine the maturation effects of FMS development in Irish primary school children (Chapter 3).

3. To ascertain if the relationship between fundamental movement skills and health related fitness is dynamic (Chapter 4).

1.4 Research questions and hypotheses

1. What are the fundamental movement skill proficiency levels of Irish children?

   Hypothesis: Irish children have poor levels of fundamental movement skill proficiency.

2. Do Irish children display gender discrepancies in fundamental movement skill proficiency?

   Hypothesis: Males demonstrate significantly greater levels of object control proficiency.

3. Do Irish children reach fundamental movement skill mastery during the primary school years?

   Hypothesis: Irish children do not master the fundamental movement skills during primary school.

4. Is the relationship between fundamental movement skills and components of health related fitness dynamic?

   Hypothesis: The relationship between fundamental movement skills and components of health related fitness is dynamic and strengthens with age.

5. Does the Moving Well-Being Well intervention have an impact on the fundamental movement skill proficiency of Irish primary school children?

   Hypothesis: The Moving Well-Being Well intervention will have a significant impact on Irish primary school children's fundamental movement skill proficiency.

1.5 Thesis Structure

Chapter 1: Introduction to Thesis

This chapter gives a broad overview of the thesis, including the aims and objectives of the study.

Chapter 2: Literature Review

This chapter gives a critical evaluation of the previous literature in areas such as: physical literacy, fundamental movement skills, health related fitness, and school based interventions. This chapter gives a comprehensive up to date review, highlighting gaps in the literature.

Chapter 3: Moving Well-Being Well: Investigating the maturation of fundamental movement skill proficiency across sex in Irish children aged five to twelve

This chapter provides a report on the fundamental movement skill proficiency of Irish primary school children. It also examines gender differences and maturation rates of fundamental movement skill proficiency.

Chapter 4: Evolving dynamics between fundamental movement skills and health related fitness components in children

This chapter examines the relationship between fundamental movement skill proficiency and components of health related fitness in Irish primary school children. It also examines if this relationship is dynamic, and which fundamental movement skill subtests contribute to certain health related fitness components.

Chapter 5: Exploring the effectiveness of the Moving Well-Being Well intervention on primary school children's motor competence

This chapter provides a report on the efficacy of the Moving Well-Being Well intervention on the fundamental movement skill proficiency in Irish primary school children.

Chapter 6: Conclusions and future direction for the Moving Well-Being Well programme

This chapter provides an overview of the thesis, presenting the main findings, strength and limitations of the study, directions for future research, and potential options to progress the Moving Well-Being Well project.

1.6 Definition of Terms

Adolescence: A transitional stage of physical and psychological human development and growth that generally occurs during the period from puberty to legal adulthood. It is often associated with teenage years (Gallahue & Ozmun, 2006).

Balance: In the context of FMS, balance is an essential prerequisite of almost all movement skills. Balance is defined as being able to maintain a stationary position throughout the movement. The static balance on one foot is an important non-locomotor skill that is used in gymnastics, dance, diving and many team sports (NSW Department of Education and Training, 2000).

Body Mass Index: A measure of body composition using a height-weight formula – Weight (kg)/Height (m^2). High BMI values have been related to increased disease risk (Corbin et al., 2006).

Children and youth: Used to describe those aged 5-18 years of age. The term children specifically refers to those aged 5-12 years and youth refers to those aged 13-18 years of age (BHF National Centre for Physical Activity and Health, 2013).

Fundamental Movement Skills: These are the basic building blocks of movement and are observable from childhood to adulthood. FMS consist of locomotor (e.g. skipping and jumping), object control (e.g. throwing and catching), and stability skills (e.g. static balance) (Gallahue & Ozmun, 2006).

Implementation fidelity: The degree to which an intervention or programme is delivered as intended.

Locomotor subtest: In the context of FMS, the locomotor subtest refers to the motor skills that require fluid coordinated movements of the body as the child moves through space (Gallahue & Ozmun, 2006).

Mastery/Near Mastery: in the context of FMS, mastery is defined as correct performance of all components of a skill. Near mastery is defined as correct performance of all components but one (Van Beurden et al., 2002).

Obesity: Excessive fat accumulation that may impair health (Corbin et al., 2006).

Object Control subtest: In the context of FMS, object control subtest assesses motor skills that demonstrate efficient movements which involve an object, such as throwing, striking, and catching movements (Ulrich, 2013).

Perceived Motor Competence: How someone perceives his/her ability to competently perform a motor task (Harter & Pike, 1984).

Physical Activity: Physical activity is described as any body movement produced by the skeletal muscles that result in a substantial increase over resting energy expenditure (Bouchard et al., 2007). Examples include, play, lifestyle activities such as walking and cycling, sport and recreational activities, household chores, and gardening (BHF National Centre for Physical Activity and Health, 2013).

Physical Education: A school subject providing children with learning opportunities through the medium of movement and contributing to their overall development by helping them to lead full, active and healthy lives (Department of Education and Skills, 1999).

Physical Inactivity: Physical inactivity is described as doing no or very little physical activity at work, home, for transport, or during discretionary time. Failing to reach physical activity guidelines is deemed detrimental to health (Bouchard et al., 2007).

Primary school education: Children are required to complete eight years of primary school education. Most often, children enter primary school approximately aged five, and complete primary school approximately aged 12 (Department of Education and Skills, 1999).

Reliability: Reliability is a determination of whether two administrations of an instrument produce a similar result (Thomas et al., 2011).

Sedentary Behaviour: Sedentary behaviour refers to activities that do not increase energy expenditure substantially above the resting level and includes activities such as sleeping, lying down, watching television, and other forms of screen-based entertainment (Pete et al., 2012). The low energy requirements distinguish sedentary behaviours from other behaviours that also occur whilst seated but require greater effort and energy expenditure, e.g. using a rowing machine (BHF National Centre for Physical Activity and Health, 2013).

Validity: Validity is a determination of the extent to which an instrument measures what we think it's supposed to be measuring (Thomas et al., 2011).

1.7 List of Abbreviations

BMI = Body mass index

BOT-2 = Bruininks Oserestky Test of Motor Proficiency, 2^{nd} edition

CI = Confidence interval

CSPPA = Children's Sport Participation and Physical Activity report

CVE = Cardiovascular endurance

DCU = Dublin City University

DCUREC = Dublin City University Research Ethics Committee

FMS = Fundamental movement skills

HRF = Health related fitness

KTK = Korperkoodinations fur Kinder

M = Mean

ME = Muscular endurance

MNM = Mastery/Near Mastery

MWBW = Moving Well-Being Well

MRC = Medical Research Council

MS = Muscular strength

MVPA = Moderate to vigorous intensity physical activity

N = Number

PA = Physical activity

PE = Physical education

PC = Perceived competence

SD = Standard deviation

SSS = Sports specific skills

TGMD = Test of Gross Motor Development

Y-PATH = Youth Physical Activity Towards Health

1.8 Delimitations

This study is delimited to primary school children, aged 5 – 12 years of age

This study used the TGMD-3, Victorian FMS assessment scale and the BOT-2 short form balance subtest to assess FMS.

The Moving Well-Being Well intervention was implemented to first- and second-class children (age 7-8 years).

The Moving Well-Being Well intervention lasted for eight weeks.

Chapter 2: Literature Review

2.1 Physical Literacy – An Introduction

The term physical literacy (PL) has had a resurgence in the last number of years, despite having its origins in the 19th century when the US army used it to reference movement quality (Maguire, 1884). Nowadays several definitions exist (Corbin, 2016), with the United Nations Educational, Scientific and Cultural Organisation (UNESCO) describing PL as "*the ability, confidence, and motivation to engage in life-long physical activity*" (2004). Mandigo and colleagues (2009) described those who are competent in a wide array of activities that help develop the person as a whole as physically literate people, with Margaret Whitehead also having contributed to the field in recent times. Her outlook focuses on the individuals experience of movement which fosters a positive attitude towards physical activity (PA) which she believes helps an individual to achieve their full potential and an improved quality of life (Whitehead, 2001). The most commonly accepted definition of PL is the "*motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life*" (International Physical Literacy Association (IPLA), 2017; Tremblay et al., 2018). Regardless of the actual definition, there seems to be an indirect consensus as all definitions contain the above components, acknowledging that being competent in motor skills to partake in physical activity (PA) is not enough, an individual must also be confident to apply these skills and engage in a variety of activities in different environments to drive lifelong participation in PA (Cairney et al., 2019; R. J. Keegan, Keegan, Daley, & Ordway, 2013; Shearer et al., 2018). Any increase in PA would lead to numerous and well established health benefits, such as a decreased risk, of cardiovascular disease, obesity, type 2 diabetes, etc (Ortega et al., 2008; Ruiz et al., 2006a). With a growing body of research highlighting the importance of PL, it seems logical to look at PL as a means of addressing the worldwide problem of physical inactivity (Shearer et al., 2018; Whitehead et al., 2018).

The IPLA definition shows that PL is made up of several components, namely: motivation, confidence, knowledge and understanding, and physical competence. Whitehead defines motivation and confidence as the ability to "*capitalise on innate movement/physical potential to make a significant contribution to the quality of life*" (Whitehead, 2013). Whitehead infers that if an individual is confident in their movement capacities in various environments, their motivation to engage in an active lifestyle should increase. The next component is knowledge and understanding. This refers to the ability to identify what is required to move effectively and to understand the basic principles of health, namely, exercise, nutrition and sleep (Whitehead, 2013). This leads to the final component, physical competence. Physical competence refers to an individual's musculoskeletal fitness and anthropometric properties (e.g. cardiovascular fitness, muscular strength, body composition) (Tremblay et al., 2018), as well as their ability to perform basic motor skills (Logan et al., 2018). These basic motor skills are commonly referred to as the fundamental movement skills (FMS). FMS are the building blocks of more advanced, complex movements that are required to take part in a variety of activities (Logan et al., 2018). If an individual is competent in these foundational skills, he/she will be confident in performing them, and their motivation to engage in activities may increase (Barnett et al., 2009c). Assessing how these four components interact with one another may be key to understanding why children choose to be active (Cairney et al., 2019). In order to understand this interaction, PL must first be measured.

Some studies have measured the various separate components of PL using a suite of existing, valid and reliable tools. There are many valid and reliable assessments for physical competence; for example, the Test of Gross Motor Development is commonly used to assess motor competence (Ulrich, 2013) and the FITNESSGRAM is widely used for physical fitness measures (Meredith & Welk, 2010). Many have researched motivation (Owen, Smith, Lubans, Ng, & Lonsdale, 2014) and confidence (Murphy, Rowe, Belton, & Woods, 2015) towards physical activity, however there is little research that measures knowledge and understanding (Edwards et al., 2018). Studies involving PL employ differing methodologies across various institutions (Edwards et al., 2018), and even within the same country. The Canadian Assessment for Physical Literacy (CAPL) (Francis et al., 2015) and the Physical Literacy Assessment for Youth (PLAY) (Cairney et al., 2018) are two Canadian tools that purport to measure all elements of PL for example. Now in its second iteration, the CAPL measures physical competence, physical fitness, motivation and knowledge, encompassed by daily behaviour (Francis et al., 2015). The physical fitness tests are those which are used commonly in research examining health related fitness in children and youths, e.g. the PACER shuttle run test to measure VO_{2max}, and an isometric plank hold test to assess muscular endurance. The CAPL measures physical competence using the Canadian Agility and Movement Skill Assessment (CAMSA), and is a measure of selected fundamental, complex and combined movement skills (Longmuir et al., 2017). Participants travel through a course and must complete movement skills including: jump, side shuffle, catch, throw, skip, hop and kick. The proficiency in which the participant fulfilled the criteria of each skill is assessed, along with the time taken to complete the course (Longmuir et al., 2017). Daily behaviour records physical activity through a daily step count where participants wear a pedometer for seven consecutive days. Finally, a physical activity questionnaire is used to assess motivation, confidence and knowledge and understanding (Francis et al., 2015).

The original CAPL prioritised the physical domain by weighting the physical components more strongly than the other constructs. This goes against some of the PL philosophies outlined by Edwards and colleagues (2018). The revised version gave equal weight to each of the physical competence, motivation and confidence, and daily behaviour components, with the knowledge and understanding component receiving just ten points (Longmuir et al., 2018). Upon completion, scores are totalled, and participants are put into one of the following categories: beginning, progressing, achieving and excelling (Longmuir et al., 2018). The CAPL is a pragmatic attempt to measure all domains of PL using quantitative and qualitative methods, however it is not without its limitations, particularly with regards the physical competence component. It could be argued that in using a time measurement for the CAMSA, participants may focus on the speed in which they complete the skills, rather than how well they perform them; i.e. focused on the product and not the process (Ulrich, 2000). The CAMSA also only captures seven skills whereas there are other measurement tools such as the Test of Gross Motor Development (Ulrich, 2000) and Bruininks Ostersky Test (Bruininks, 2005) that encompass a more extensive range of skills.

There are several PLAY tools (physicalliteracy.ca/play-tools/), designed to be used by the various stakeholders that may be involved in developing a child's PL, and the PLAYfun is the most utilised resource (Cairney et al., 2108). The other PLAY tools include: PLAYbasic, which is a simpler version of PLAYfun, the PLAYself which allows the child to assess themselves, the PLAYinventory in which the child reports their own PA, the PLAYparent where the parent assesses the child's PL, and the PLAYcoach which is a tool for the coach or PE teacher to use to assess children (Cairney et al., 2018; Kilborn, Lorusso, & Francis., 2016). Recently a prePLAY resource has also been developed for use in preschool children (Cairney et al., 2018). The PLAYfun measures physical competence, confidence and knowledge. The physical competence component is assessed through a series of FMS that are linked to the physical education curriculum (Cairney et al., 2018). The scoring system uses a visual analog scale for rating each skill and raters assess children along a continuum, which allows for greater variability in scoring. This differs from many of the commonly used FMS assessment tools which either measure the product or the process of the skill; i.e. the outcome of the skill or how the skill was performed (Cairney et al., 2018). The rater also subjectively rates the participant's confidence, marking low, medium or high confidence for each task. The participant's knowledge of each task is also assessed through the rater noting whether the child needed: an encouraging prompt, a demonstration from the assessor, a description of the skill, or for another child to complete the task so that it could be mimicked. Upon completion, participants are placed into initial, emerging, competent and proficient categories. While the PLAYfun provides greater variability in assessing the FMS, this comes with its own limitations. The visual analog scale is unique and as such does not allow for comparisons to other measures of motor competence. Additionally, the sample size used to validate the tool was not large enough for the statistical analyses used (Cairney et al., 2018) and as such should be replicated with a larger cohort. Further research is need to validate the PLAY tools before they can be accepted as an established method for measuring PL.

While there is no clear PL assessment agreed upon in the literature, there is a consensus over the components of PL, which are outlined in the IPLA's definition (International Physical Literacy Association, 2017). The concept of PL, while not being new in historical terms, could be considered to be in its infancy in research involving children's health. While many studies have attempted to increase PA (Fletcher, 2009), few have investigated how PL can be developed in children. Emerging research suggest that PL could be a key determinant in engaging children in lifelong PA (Cairney et al., 2019; Tremblay et al., 2018). Given the well-established health benefits associated with PA, it seems logical that examining the PL components in children, along with how they interact with one another, should be a key focus of further research, providing critical information which could inform, for example, future intervention strategies. As previously discussed, however, the measurement of PL has proven troublesome (Edwards et al., 2018). PL is a multi-faceted complex construct, and while acknowledging the value each component has towards being active for life, it is important to delve into some of the constructs in detail, such as physical competence, in order to gain a deeper understanding. The physical competence component comprises of both an individual's health related fitness properties (Tremblay et al., 2018), and their motor skill proficiency

(Logan et al., 2018). These basic skills are commonly referred to as the fundamental movement skills (FMS) and will be examined in detail in the next section.

2.2 Fundamental Movement Skills

Introduction

Fundamental movement skills (FMS) are the basic building blocks of more advanced complex movements that support successful engagement in sport or physical activity (PA) (Logan et al., 2018b). There are three components which make up FMS: locomotor, object control and stability skills (Gallahue & Ozmun, 2006). Locomotor skills involve moving the body (e.g. running, hopping, jumping), object control skills are those which involve manipulating an external object (e.g. throwing, catching, kicking), while stability skills involve balancing skills (e.g. static balance, beam balance, one foot balance) (Gallahue & Ozmun, 2006). Children have the potential to master most of these movement skills as early as six years of age (Gallahue & Ozmun, 2006), and mastery of all FMS should be acquired by nine or ten years of age (Hardy, King, Farell, Macnivin, & Howlett, 2010). Once refined and combined, these FMS support the acquisition of more advanced movement skills that allow participation in sport or PA (McKenzie & Lounsbery, 2008; Metcalfe & Clark, 2002). Traditionally, it was believed that these skills would develop naturally but this is a common misconception, with research showing that FMS must be taught and developed (Clark, 2007; Haywood & Getchell, 2019; Cools et al., 2009; Stodden et al., 2008). Girls and boys do not, however, typically progress to mastery level at a similar rate (Cliff, Okely, Smith, & McKeen, 2009).

The literature would suggest a variance in FMS proficiency between sex in children of the same age, with girls displaying higher proficiency locomotor and stability skills, while boys typically achieving higher scores than girls in object control skills (Barnett et al., 2009; Erwin & Castelli, 2008; Goodway, Robinson, & Crowe, 2013; Hardy et al., 2010). As children master the FMS, they refine and link these skills to produce sports specific skills, or develop skills that allow for various forms of PA in which the skills are required (McKenzie & Lounsbery, 2009; Robinson, et al., 2015). For example, if a child can run, jump and catch, they will be able to link these together to perform an overhead catch in Gaelic football. Another example, if a child has the basic skills of run, throw, strike and catch, they can then link those skills together to play baseball. The opposite is also true, a lack of FMS proficiency will have consequences in relation to reduced PA participation (Jaakkola, Yli-Piipari, Houtari, Watt, & Liukkonen, 2016). Seefeldt (1980) suggested a proficiency barrier, hypothesising that there is a critical threshold of motor competence, and individuals above this threshold will use their FMS proficiency to successfully partake in physical activities. In contrast, if an individual is below this barrier, then they will not have the required skill level to participate and will be more likely to drop out of physical activities (Seefeldt, 1980). The evidence shows positive associations between FMS proficiency and increases of PA in children (Barnett et al., 2009; Cliff et al., 2009; Robinson et al., 2015) and adolescents (Lubans et al., 2010; Okely et al., 2001). Many researchers now argue that mastering FMS early in childhood will lead to a more active lifestyle through the teenage years and beyond (Barnett et al., 2009; Hardy et al., 2013; Jaakkola et al., 2016; Stodden et al., 2008).

Importance of FMS in the School Setting

The school setting is considered a key setting to develop FMS (McKenzie & Lounsbery, 2009), particularly during the physical education (PE) lessons. Primary school is a particularly salient environment for children with PE identified as an important contributor towards an active lifestyle (McKenzie & Lounsbery, 2014). The importance of FMS being taught by qualified professionals has been acknowledged (Strong et al., 2005) while Okely and Booth (2004) maintain that FMS should be a part of any primary school curriculum. In Ireland, the Children's Sport Participation and Physical Activity (CSPPA) report notes that FMS programmes aimed towards developing skills in children are warranted (Woods et al., 2018). The Irish primary school PE curriculum does have a focus on FMS, "stressing personal and social development, physical growth and motor development" (Department of Education, 1999, p.6). Given these intentions, and the CSPPA reports recommendation, it is worrying to observe that Irish children have such low levels of FMS mastery (Bolger et al., 2018; Farmer et al., 2017; Kelly et al., 2018). One possibility could be down to the lack of specialised PE teachers at primary school level in Ireland. The Irish system utilises generalised teachers at primary level, and these teachers are expected to guide children through 12 curriculum subjects per week. Of the normal 27.5 hour school week, just one hour is allocated to PE in Irish primary schools (Department of Education and Skills, Government of Ireland, 1999). Ireland, alongside Norway and Malta, is among one of only three countries in Europe who doesn't have a formal PE assessment in primary school (Physical Education and Sport at School in Europe, Eurydice Report, 2013), and this may suggest that PE is not perceived as important as other formally assessed subjects (e.g. maths and literacy). In a secondary school setting, where Irish teachers specialise in PE, there is a lack of curriculum continuity as there is no emphasis on FMS in PE. This may be based on the assumption that children have developed FMS naturally during primary school. As previously mentioned (Cools et al., 2009), this is not the case when looking at the low levels of FMS proficiency observed in Irish adolescents (O'Brien et al., 2016). This assumption seems misguided. While there are independent, evidence driven, national programmes at secondary school level that seek to develop FMS, such as the Youth Towards Physical Health (Y-PATH) programme (Belton, O'Brien, McGann, & Issartel, 2019), none exist at primary school level.

Other countries have promoted FMS in the school setting more prominently, with the National Association for Sport and Physical Education (NASPE) in the USA stating the importance of motor skills in their definition of the physically educated individual (1995). Research emanating from America heavily features FMS promotion in schools (McKenzie & Lounsbery, 2008; McKenzie & Lounsbery, 2009; McKenzie et al., 2009), and the American Heart Association highlighted the importance of FMS development in children towards lifelong PA participation (Pate et al., 2006). These recommendations have been addressed through several initiatives and one such example is the Sports, Play and Active Recreation for Kids (SPARK) PE programme, which aims to develop FMS through age appropriate PE activities (McKenzie et al., 2009). In the southern hemisphere, Australian programmes such as 'Get Skilled: Get Active' and 'Move it Groove it' aid teachers in developing FMS in both the PE and school sport settings (Department of Education and Training, 2000; Van Beurden et al., 2003). Others target specific demographics, such as the Supporting Children's Outcomes using Rewards, Exercise and Skills (SCORES) intervention, which was designed for low socio-economic status communities in the USA (Cohen et al., 2015). Perhaps one of the most established initiatives is 'Project Energize' in New Zealand which has been in operation since 2005 (Rush et al., 2016). This has proven highly successful in increasing FMS levels across 242 schools (Mitchell et al., 2013) and an Irish version of the programme, 'Project Spraoi' has reported similar results, albeit with small sample sizes (Bolger et al., 2019). Several systematic reviews examining FMS based intervention in schools have shown significant improvements in FMS proficiency (Lai et al., 2014; Logan, Robinson, Wilson, & Lucas, 2012; Lubans, Morgan, Cliff, Barnett, & Okely, 2010), and it is clear that the school setting is particularly effective for increasing motor competence.

The literature is consistent in emphasising the need to develop FMS in the school setting, and research investigating the importance of PE has shown the benefits of developing FMS towards the student's development of skills which will contribute to lifelong engagement in PA (Tsangaridou, 2012). With the growing evidence linking FMS to PA, and the associated health benefits, it seems clear that there should be an emphasis on developing FMS in children. In addition, assessing FMS in primary schools would allow comparison to normative scores and allow for longitudinal measurement to track progress. To this end, an effective and relevant measurement tool must be used to assess FMS development. While the initiatives and interventions mentioned above have all proven effective at improving FMS proficiency, it is interesting to note that several different measurement tools were used to assess FMS. The next section will look at the various forms of assessing motor competence.

Measurement of Fundamental Movement Skills

It is clear that FMS are important in a child's development and the research indicates that FMS must be targeted and developed early in life (Stodden et al., 2008). This creates the need for FMS assessment tools to measure current levels and to assess the impact of interventions (O'Brien, Belton, & Issartel, 2016; Hands et al., 2008). There are a wide variety of assessment tools available, some of which are suitable for different age groups and all have varying protocols. All tools have a product or a process based methodology, with some employing both methods. Product based is measuring the result of an action, e.g. the speed the ball is thrown, whereas process based is focused on examining the underlying technique used in an action, e.g. how the ball was thrown (Burton & Miller, 1998). Process based assessments are viewed as the most informative due to the component nature of each skill. This allows an assessor to identify components of weakness and allocate specific feedback when needed (Ulrich, 2000). In addition, only process measures allow the observer to distinguish between technical development and development due to physical growth and/or maturation. There are a variety of both product and process based FMS assessment tools to choose from when working with children (Griffiths et al., 2018). The most commonly used product based assessments are the Movement Assessment Battery for Children (MABC) (Henderson et al., 2007) and the Korperkoodinations Test fur Kinder (KTK) (Kiphard & Shilling, 2007).

The KTK is validated for children aged five to 14 (Cools et al., 2009) and consists of four subtests; walking backwards, moving sideways, hopping for height, and jumping sideways, of which the outcome of each is measured (Vandorpe et al., 2011). The KTK has been used extensively in research (D'Hondt et al., 2012; Vandendriessche et al., 2012; Vandorpe et al., 2012), however, it has some limitations. The tool only records the overall gross FMS score, and there is no breakdown of the FMS components, even though the four assessments focus on stability skills (Cools et al., 2009). The normative data provided is also relatively old (circa 1974) and may not still be relevant (Cools et al., 2009).

The MABC-2 (second edition) is suitable for children and youth, aged three to sixteen (Henderson, Sugden, & Barnett, 2007), and is used to identify impairments in FMS across three skill categories: manual dexterity, aiming and catching, and balance (Henderson et al., 2007). It has been used over several age ranges (Fisher et al., 2005; Livesey, Lum Mow, Toshack, & Zheng, 2011; Vedul-Kjelsås, Sigmundsson, Stensdotter, & Haga, 2012; Gísladóttir, Haga, & Sigmundsson, 2014), and the tasks change based on the participant's age (Brown & Lalor, 2009). Normative scores are provided for each age category (3-6 years, 7-10 years, 11-16 years) and individuals at risk of movement difficulties are identified using a traffic light system. The MABC-2 is advantageous over the KTK due to the fact that it assesses all three components of FMS, and that an assessor can focus on just one component without having to complete the full test battery. The main limitation of the MABC-2, as is the case in all product based assessments, is the fact that it does not identify movement quality – i.e. if the components of a skill are correctly executed during their execution. Some researchers have combined product and process based assessment techniques in order to measure FMS (Rodrigues, Stodden, & Lopes, 2016; Stodden, True, Langendorfer, & Gao, 2013; Stodden, Langendorfer, & Robertson, 2009). In these cases, a participant was asked to perform a skill (e.g. throwing a ball) and the process of how the participant executed the components of the skill was assessed, with the outcome of the skill also being measured (e.g. the speed of the ball). These techniques can be used to overcome a potential ceiling effect for older children and adolescents in some process based FMS assessments (Logan et al., 2017), but disparities between gender tend to be highlighted when outcome based measures are used, particularly in adolescence due to physiological changes during puberty (True, Brian, Goodway, & Stodden, 2017).

Another form of FMS assessment is the Bruininks-Oserestsky Test of Motor Proficiency (BOTMP) and the Bruininks-Oseretsky Test Second Edition (BOT-2) (Bruininks, 2005). These tests are different to the other assessments due to the fact that it assesses both fine and gross motor skill development and is used primarily to identify those with mild or moderate motor coordination difficulties. It is suitable for those aged between four and 21 years of age and the complete test consists of eight sub domains containing 53 items of assessment, although there is a short form version (Bruininks, 2005). Despite the BOT-2 being an extensive assessment, there are some limitations. The complete test takes approximately 45-60 mins, with the short form taking between 15 and 20 minutes (Cools et al., 2009), making it impractical for assessing large numbers, particularly in a school setting (Peerlings et al., 2007). It also doesn't assess as many skills as other tools so does not provide an assessor with a full picture of a participant's FMS.

Australia has been a leader in FMS promotion and in developing practical assessment tools. A process based FMS assessment, the Victorian Fundamental Motor Skills manual, was first used in the 1990's and is still used to this day (Department of Education Victoria, 1996, Fundamental Motor Skills: A Manual for Classroom Teachers, Melbourne: Education Department of Victoria). It is comprised of four locomotor skills (run, vertical jump, leap and dodge) and six object control skills (catch, kick, ball bounce, punt, forehand strike and two-hand side-arm strike). This tool formed the basis for the 'Move it Groove it' programme, which used several process based assessment techniques with the FMS testing derived from the original Victorian Fundamental Motor Skills manual (van Beurden et al., 2002). The 'Move it Groove it' project added several skills (static balance, side gallop, hop, and overhand throw), as these were identified as vital to the development of sports specific skills (van Beurden et al., 2002). This project had its limitations, with differing objectives from the three organisations involved, resulting in a minimalist approach and minimal data collection. The 'Get skilled: Get Active' assessment tool was developed as part of another Australian FMS teaching resource of the same name. Again, this process orientated assessment consists of locomotor (run, vertical jump, hop, side gallop, skip, leap, and dodge) and object control skills tests (catch, overarm throw, kick, and two-handed strike), while also measuring balance, thus making it one of the only process based assessments to include all three FMS components (Gallahue & Ozmun, 2006; Rudd et al., 2015). Similar to the 'Move it Groove it', the 'Get Skilled: Get Active' included the selected skills based on what were considered to form the foundation of sports specific skills (Okely & Booth, 2004). 'Get Skilled: Get Active' breaks each skill down into observable components that allow the proficiency level of each skill to be assessed (Okely & Booth, 2004). It is recognised as a reliable tool for assessing FMS , however, there are questions over its validity with concerns highlighted by Barnett et al. (2010, p.168) showing that its “validity was not assessed in terms of whether the specialised skill features reflected the proficient performance compared to that specified in the current literature”.

One of the most common forms of assessing FMS is the process based Test of Gross Motor Development (TGMD) (Ulrich, 2017). The TGMD-2 has been extensively used in research (Belton, O'Brien, Meegan, Woods, & Issartel, 2014; Logan et al., 2017; O’Brien et al., 2016; O’Brien, Issartel, & Belton, 2013; Khodaverdi, Bahram, Stodden, & Kazemnejad, 2015; Barnett, Morgan, van Beurden, & Beard, 2008). Now in its third iteration, the TGMD-3 contains six locomotor skills and seven object control skills (Ulrich, 2013), and includes one more skill than the previous TGMD-2 with the addition of the one handed strike. Each skill is made up of between three and five components and these are assessed in order to determine the proficiency level of the participant. A participant performs a familiarisation trial version of the skill, then two trials in which the skill components are assessed. The TGMD-2 was designed for children between the ages of three and ten, and has been widely used due to its high validity and reliability (Cliff et al., 2011; Hardy et al., 2010; O’Brien et al., 2016). Recently, it has been validated as a reliable tool for measuring FMS in adolescence (Issartel et al., 2017) which means it can be used for the full primary school lifespan. The TGMD-2 provides normative scores for both the locomotor and object control skill subtests, with gender specific tables for the object control subtest (Ulrich, 2000). Normative values for the TGMD-3 are currently being compiled and are set to be published later in the year. The TGMD-2 is also validated for various populations across ethnicities, countries and specific disabilities (Houwen, Hartman, Jonker, & Visscher, 2010; Yee, Wong, & Cheung, 2010), a recent meta-analysis recommends the TGMD-2 for use in research (Logan, Robinson, Wilson, & Lucas 2012). It seems logical to use the latest edition, the TGMD-3, as an assessment tool due to the addition of an extra skill. In summary, the TGMD-3 has shown itself to be the gold standard of FMS assessment tools and is the most appropriate tool available in a mainstream setting. It is, however, not without its limitations. It fails to assess stability (Rudd et al., 2015a) which, along with locomotor and object control skills, is a key component of FMS (Gallahue & Ozmun, 2006).

Another limitation, which is not just true for the TGMD-3 but for all the aforementioned measurement tools, is that traditionally all the assessments are measured using a pen and paper method. This is a time consuming exercise, doubly so when factoring in the time spent entering the results into a database for analysis. This time constraint can significantly impact the amount of data collected, not to mention the risk of human error in the data entry process. Some researchers have taken steps to try to modernise this process through technology and innovative apps (van Rossum & Morely, 2018), but there are still issues with scalability and data protection. Despite these limitations, there are a wide variety of assessment tools utilised in the research that can assess FMS accurately and reliably (Logan et al., 2012). Irrespective of which tools are used, the results from these assessments show alarmingly low levels of FMS proficiency reported worldwide (Barnett et al., 2009; Kelly et al., 2018; Lubans et al., 2010; Mukherjee, Ting, & Fong, 2017).

FMS Proficiency including Gender Differences

The proficiency levels reported in children and adolescents is low worldwide (Barnett et al., 2009; Kelly et al., 2018; Lubans et al., 2010; Mukherjee et al., 2017). As mentioned previously, each FMS is compiled of several behavioural components that must be present for successful skill completion, and are described as performance criteria (Ulrich, 2000). One must be proficient in all the criteria required of a skill to be deemed proficient in any FMS. For example, to be proficient at running in the TGMD-3, an individual is required to adhere to the following criteria: 1) Arms move in opposition to legs with elbows bent, 2) Brief period where both feet are off the surface, 3) Narrow foot placement landing on heel or toes (not flat-footed), and 4) Non-support leg bent about 90 degrees so foot is close to buttocks (Ulrich, 2017). When describing FMS proficiency, the terms “mastery” and “near mastery” are often used in the literature. Mastery of a skill is the presence of all skill components in both trials, whereas near mastery of a skill is when an individual performs all but one component correctly over the two trials (van Beurden et al., 2002). Any participant who does not fulfil the criteria to achieve mastery or near mastery (MNM) status is classified as poor (Booth et al., 1999). This is a useful format for comparative purposes, as researchers who have used various process based FMS assessments can use MNM as a comparative tool.

According to Gallahue and Ozmun (2006), children have the potential to master most of the FMS by six years of age, while others believe all FMS can be mastered by ten years of age (Hardy et al., 2010). It seems reasonable to expect, therefore, that children have mastered most of the basic motor skills by the end of primary school. Beginning with the youngest cohort, 0% FMS mastery were reported among two to six year old preschool children (n = 425) in Australia (Hardy et al., 2010). This result is to be expected as children are only expected to master most of the FMS at age six (Gallahue & Ozmun, 2006). Given that mastery is not expected in preschool children, one might expect to see increases in FMS levels as children progress through primary school. This is not the case, as multiple studies report children below the expected FMS proficiency levels (Barnett et al., 2009; Kelly et al., 2018; Lubans et al., 2010; Mukherjee et al., 2017; Okely & Booth, 2004). Australian children (n = 1288, six and nine years of age) did not show above 35% mastery in any of the six FMS skills assessed (Okely & Booth, 2004). Prevalence of near mastery did not exceed 50% across the skills, with the exception of balance (Okely & Booth, 2004). Another Australian study found that less than half the children (47%) achieved MNM in FMS (van Beurden et al., 2002). A recent article reports children in Singapore were rated 'average' or 'below average' for locomotor skills and 'poor' or 'below average' for object control skills (Mukherjee et al., 2017), and Bardid et al. (2016) showed Belgian children (n = 1614, age three to eight) rate poorly against the normative scores of the TGMD-2 (Ulrich, 2000). Within the Irish context, a study looking at primary school children (n = 414, age six to 12) highlighted poor levels of FMS mastery (Kelly et al., 2018). Kelly and colleagues (2018) found low levels of MNM in several skills, such as: run at 42.7% MNM, gallop at 37.1% MNM, hop at 27.5% MNM, two-handed strike at 22% MNM, one-handed strike at 34.6% MNM, and vertical jump at 22.2% MNM. These findings have limitations however, due to the lack of generalisability in the convenience sample consisting of only three primary schools (n = 414) (Kelly et al., 2018).

The research is consistent in showing males scoring significantly higher than females in the object control skills (Bardid et al., 2016; Barnett et al., 2010; Kelly et al., 2018; Okely & Booth, 2004; van Beurden et al., 2002). Okely and Booth (2004) show similar levels of mastery across gender in the locomotor skills, however the study did show males score significantly better in the object control skills. Looking at children at ten years of age, the findings in various studies (Bardid et al., 2016; Barnett et al., 2010; Kelly et al., 2018) mirror these results, with males again outperforming the girls in object control skills. Research in Ireland and Belgium has produced the same results (Bardid et al., 2016; Kelly et al., 2018). Gender differences have not been found to be as pronounced with the locomotor skills. Some have found significant gender differences in locomotor skills, with females achieving higher proficiency in the locomotor skills (Cliff et al., 2012; Hardy et al., 2010), whereas others have found no significant differences between gender (Bardid et al., 2016; Kelly et al., 2018). It should be pointed out that these studies also show males significantly outperforming females in the object control skills. Van Beurden et al. (2002) suggests that sport participation may explain this gender disparity, with girls favouring locomotor skill dominant activities such as gymnastics, dance, etc., and boys favouring activities predominantly involving object control skills such as football, rugby, etc. When looking at the Irish population, we can see from the CSPPA report (Woods et al., 2018) that soccer, Gaelic games and basketball are among the most popular sports for males, whereas the females partake in more athletics and dance than the males. Independently of the underlying reasons, gender differences in FMS proficiency are a vital consideration. Furthermore, the analysis of each of the three components (locomotor, object control and stability) is key to determine differences. Opposing differences could cancel each other out if males scored higher in object control and lower in locomotor, and females scored higher in locomotor and lower in object control (Fisher et al., 2005). This could lead to both males and females attaining the same overall FMS score. Any gender discrepancies will not be apparent if only the overall FMS score is reported (Fisher et al., 2005).

There is not as much focus on FMS in the adolescent population, primarily due to the fact that they should be concentrating on sports specific skills, yet the research shows that they are not at the proficiency level required to progress (Booth et al., 1999; Hardy, Barnett, Espinel, & Okely, 2013; Hardy et al., 2010). Irish research shows that only 11% of adolescents (n = 242, 12 to 13 years old) have acquired MNM across nine FMS skills (O'Brien et al., 2016). Gender differences were also shown to be in line with the children's research with males outperforming the females in object control skills. A more targeted look in Irish adolescents also shows low competence in the overhand throw (O'Keeffe, Harrison, & Smyth, 2007). These results are hardly surprising, given the low proficiency levels reported of FMS levels in Irish children. Few studies have examined FMS proficiency longitudinally, with Barnett et al. (2010) one of the exceptions by assessing competence at ten and 16 years of age. The results found low levels of FMS proficiency at age ten but observed improvements at age 16, with 80% of males acquiring mastery in five skills, and 80% of females achieving mastery in three skills. The same gender disparities were reflected, but results also show that males progressed their object control skill proficiency to a greater extent than females over time (Barnett et al., 2010). To date no Irish research has assessed FMS longitudinally across the primary school lifespan. There is some cross sectional data, although these consist of small localised samples where findings cannot be generalised as a national representative sample (Bolger et al., 2018; Farmer et al., 2017; Kelly et al., 2018). It seems important to consider an assessment of a national representative cohort to understand the current proficiency levels of Irish children's basic movement skills.

FMS as a precursor to Sports Specific Skills

According to Gallahue and Ozmun (2006), children must master the FMS as a precursor for the acquisition of more advanced sports specific skills (SSS). SSS are FMS refined and combined to form complex and specific movement skills used in sport and other activities (Gallahue & Ozmun, 2006). Proficiency in these SSS is proposed to be heavily dependent on the mastery levels of FMS (Hardy et al., 2010). As previously mentioned, the worldwide levels of FMS proficiency are startingly low, with Irish children and adolescents no different (Kelly et al., 2018; O'Brien et al., 2016a). Kelly et al. (2018) suggests that improvements in FMS plateaued after ten years of age, while O'Brien and colleagues (2016) showed that some skills actually decline in adolescence. This supports other data that reports children may be transitioning into adolescence without first acquiring mastery of the FMS (Lubans et al., 2010). It seems illogical to assume that youths with low levels of FMS will partake in sports which involve more complex SSS. The CSPPA report states that Gaelic games are among the most popular sports in Ireland, played by males and females alike (Woods et al., 2018). How are youths expected to play Gaelic football, a sport which requires numerous complex SSS such as multiple changes of direction while controlling a ball with both hands and feet, all while being challenged by an opposing player, if they have not first mastered the basic FMS. Equally, how would one expect a youth to play a game of basketball without first mastering the basic skills such as running, bouncing a ball and jumping. Poor levels of FMS proficiency may be part of the reason why adolescents choose to drop out of sport (Jaakkola et al., 2016). Children and youths perception of their ability to perform these skills are also thought to be a contributing factor to participating in sport and PA in general (Barnett et al., 2015).

Perceived FMS Competence

In reviewing the literature on FMS above, FMS competence refers to the actual physical ability of an individual to perform a skill. While actual FMS competence is imperative, it is also important to consider perception of competence. Perceived competence (PC) has been described as a person's belief in their capacity to master a task (Feltz, 2007). Harter's

Competence Motivation theory defines PC as an individual's perception of their physical abilities to perform successfully in specific domains (Harter, 1982; 2012).

There is a positive association between PC and PA participation (Bailey, Boddy, Savory, Denton, & Kerr, 2012; Baker & Davison, 2011; Crocker, Eklund, & Kowalski, 2000; Davison, Schmalz, & Downs, 2010; De Meester et al., 2016; Ekelund et al., 2012; Hills, Andersen, & Byrne, 2011; Susi Kriemler et al., 2010; Raudsepp, Liblik, & Hannus, 2002; Warburton, Nicol, & Bredin, 2006; Zhang, Thomas, & Weiller, 2015), and it seems prudent to take a more detailed look at PC and how it relates to FMS. According to Harter (1999), PC changes across a child's development, and younger children demonstrate a limited ability to perceive their competence resulting in inflated levels of PC. In simple terms, a young child may have low levels of actual competence, but still perceive themselves as being highly skilled (Harter & Pike, 1984). This inflated sense of PC may be a valuable tool as children will be more likely to persistently engage in activities in which they believe they are already proficient which will in turn drive PA and the development of actual FMS (Stodden et al., 2008). As children grow and develop, their ability to accurately perceive their competence will increase over this time (Harter, 1999). At this stage, those with a poor skill level will also perceive themselves as lowly skilled, and this can result in physical inactivity. They may realise they are not as good as their peers (Goodway & Rudisill, 1997; Weiss & Amorose, 2005), and may feel self-conscious displaying their poor competence in public (Horn & Weiss, 1991; Weiss & Amorose, 2005). The simple fact of having low skill competence could mean that children are less motivated to take part in PA (Bardid et al., 2016). Stodden and colleagues (2008) produced a conceptual model (see Figure 2.1) outlining PC and FMS, along with health related fitness (HRF) and PA, as key components towards a positive health trajectory. They argue that children with poor FMS proficiency and low PC will be "*drawn into a negative spiral of disengagement*", resulting in physical inactivity and the negative health consequences associated with it (Stodden et al., 2008, p.296).

The opposite side of the argument is that a "*positive spiral of engagement*" can also take place, one in which children who possess high levels of FMS proficiency and PC will be more likely to take part in PA (Stodden et al., 2008, p. 296). If this is the case it would seem logical to measure both FMS and PC longitudinally and measure the impact, if any, on PA. Barnett et al. (2009) did exactly that and found that children who had both high actual and perceived competence in object control skills went on to be more active in adolescence than their less proficient peers. Another study from the same group showed a strong correlation between children’s perception of their object control skills to their actual competence (Barnett, Ridgers, & Salmon, 2015). A paper looking at pre-school children has shown correlations between PC and both locomotor skills and object control skills (Robinson, Wadsworth, & Peoples, 2012). While the findings above mentioned no significant gender differences, a recent study conducted in Finnish children (n = 422, age = 11.26 ± 0.31) with aligned perceived and actual motor competence, suggests the impact on PA levels is different for boys and girls (Jaakkola et al., 2019). While they found that motor competence and PA were directly associated only for the boys’ group, they also demonstrated an indirect path to PA engagement for the girls’ group through PC (Jaakkola et al., 2019). This would suggest that PC may be more important for girls in terms of future PA participation, particularly in this preadolescence phase when the opinions of their peers begin to garner more weight. The same findings suggest that PE teachers should focus on developing girls PC in order to promote continued participation in sport and PA. The findings highlight the need for future research and interventions to target PC in children and youth (Barnett et al., 2009), and in order to do this, methods of measuring PC must be explored.

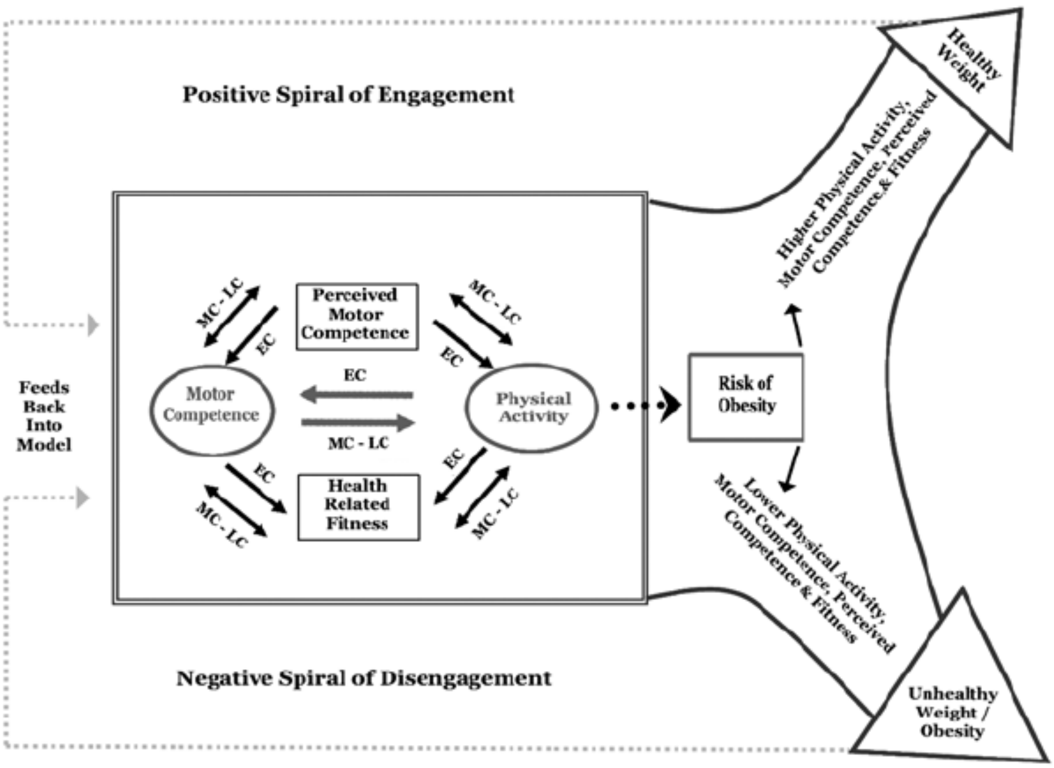

Figure 2.1 Stodden and colleagues (2008) conceptual model outlining the developmental mechanisms influencing PA trajectories of children.

Measurement of Perceived FMS Competence

Harter and Pike (1984) reported psychometric data supporting a PC construct being divided into 'physical competence' and 'cognitive competence', and from this designed the Pictorial Scale of Perceived Competence and Acceptance for Young Children to measure physical self-perceptions in children. While this scale assesses typical childhood actions (e.g. swinging on a swing), it does not assess FMS in a comprehensive manner. Some instruments have been developed to more accurately measure PC of the most common FMS skills. The Children's Perception of Motor Competence Scale was developed and used in Spain (Pérez & Sanz, 2005) but this failed to encompass all the FMS, neglecting to include common object control skills such as kicking and striking. Research involving FMS proficiency most often assess a range of locomotor and object control skills, and as discussed already, the TGMD is one of the most commonly used assessments (Logan et al., 2012). Barnett et al. (2015) developed the Pictorial Scale of Perceived Movement Skill Competence for Young Children aligned with the TGMD.

The scale consists of 13 skills, in line with the TGMD-3, and each skill is depicted through two cartoon pictures of a boy or a girl performing that particular skill (Barnett et al., 2015). In one picture, the child is performing the skill well, and in the other the child is not performing the skill well. Using running as an example, the participant is asked to choose the picture that they feel is most similar to their own performance of running. If the picture performing running well is chosen, the participant is then asked if they feel they are 'really good art running' or 'pretty good at running'. If the participant chose the other picture, they would answer 'sort of good at running' or 'not too good at running'. A score of four points is awarded for the highest perceived competence, i.e. 'really good at running', with just one point for the lowest perceived competence, i.e. 'not too good at running', with a score of two or three points assigned for the other two answers. This scale has been widely used in research due to its validity and reliability (Barnett et al., 2015). The pictorial scale is traditionally employed using a pen and paper method with the research team manually inputting the scores into a database for analyses upon completion. The instrument can be used to accurately assess perceived FMS competence in young children and is particularly useful as a comparison tool when using an iteration of the TGMD to measure actual FMS proficiency (Barnett et al., 2015).

Benefits of Fundamental Movement Skills

A systematic review carried out by Lubans et al. (2010) looked at FMS in children and all the associated health benefits. These included perceived benefits from the physical, cognitive and social development domains. One of the main findings was a strong relationship between FMS and PA particpation. FMS proficiency and habitual PA are positively associated in children and adolescents (Barnett et al., 2009; Fisher et al., 2005; Jaakkola et al., 2016; Okely et al., 2001). The review indicated positive relationships between FMS proficiency in children and adolescents with: overall PA (Fisher et al., 2005), organised PA (Okely et al., 2001), and MVPA (Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). Increasing PA can lead to a multitude of health benefits such as reduced risk of cardiovascular disease, increased bone health and less chance of obesity (Ortega et al., 2011; Pate et al., 2012; Rizzo, Ruiz, Hurtig-Wennlof, Ortega, & Sjostrom, 2007; Ruiz et al., 2006a). Evidence of the relationship between FMS and PA is largely cross sectional however, and it must be highlighted that these relationships cannot be seen to be causal.

Those with low FMS proficiency have been reported to be at risk of low levels of PA participation (Barnett et al., 2009; Lopes et al., 2011; Lloyd et al., 2014). Lopes and colleagues (2011), showed that FMS levels at age 6 (n = 285; 6 years of age) was a significant predictor of PA over a five year longitudinal study. The highest FMS performers maintained their PA levels over time, whereas those in the lowest FMS proficiency category declined in PA during childhood (Lopes et al., 2011). This was in spite of a trend globally showing decreased PA participation with age (Borraccino et al., 2009). The same study categorised the participants by FMS proficiency (low, medium, and high competency) and found that there were no significant differences in PA at age six, but by age ten, there were significant differences in PA favouring the higher performing FMS group (Lopes et al., 2011). This could indicate that the negative consequences of poor FMS may not develop in early childhood, but later in life.

Another longitudinal study by Barnett and colleagues (Barnett et al., 2009) found that high levels of object control skills competence as a child is positively associated with increased levels of PA in adolescence. The participants who demonstrated great object control proficiency at age 10 (n = 276) reported higher vigorous PA at the age of 16 than those who were less skilled (Barnett et al., 2009). A longitudinal study looked at participants (n=100) FMS and PA levels over 20 years, measured at four timepoints (Lloyd et al., 2014). Participants categorised in the low FMS proficiency group at age six showed little improvement in FMS after five years (mean raw score 36.5 at age 6 to 40.8 at age 11) and less time spent being active than those in the higher FMS competency group (Lloyd et al., 2014). The subsequent follow up at years 15 and 20 of the same group reported lower levels of PA at age 16 (n=43) and age 26 (n=17) (Lloyd et al., 2014). The participants who were identified as the high FMS performers were those who reported the highest levels of MVPA as adults (62.7 minutes for high FMS group versus 31.7 minutes for low FMS group) (Lloyd et al., 2104). Given that FMS proficiency as a young child could have a direct impact on PA participation in the future, and the numerous positive health benefits associated being physical active, highlights the importance of developing FMS in children (Lloyd et al., 2014; Lopes et al., 2011; Barnett et al., 2009).

It would be remiss not to mention some longitudinal research has not found any association between FMS proficiency as a child and future PA participation. One study found that while it was true for boys, childhood FMS did not predict later PA in girls (Green et al., 2011). Another found that FMS levels at ages four, five and six (n=207), failed to predict PA at age 12 in either gender (McKenzie et al., 2002). McKenzie and colleagues (2002) study is, however, in contrast to the vast majority of research (Lloyd et al., 2014; Lopes et al., 2011; Lubans et al., 2010; Barnett et al., 2009; Stodden et al., 2008). In general, the research appears to show an association between childhood FMS proficiency and PA participation later in life. The direction of this relationship does cause some debate, the 'chicken or the egg' argument, with some questioning whether FMS proficiency increases due to increased PA, rather than vice-versa. While those with this opinion may be in the minority, there is an established link between FMS and PA (Lloyd et al., 2014; Lopes et al., 2011; Lubans et al., 2010; Barnett et al., 2009).

Others have looked at the relationship between FMS and PA as part of a wider construct, suggesting that there are other variables at play. Stodden et al. (2008) puts forward a conceptual model that FMS, PC and HRF and PA interact to produce positive or negative trajectories towards health. In recent months, a Finnish research group have produced evidence to support this model (Jaakkola et al., 2019). They demonstrated significant indirect paths from motor competence to PA engagement through PC for girls but not boys, which is in contrast to a systematic review suggesting no gender differences in the PC-PA relationship (Babic et al., 2014). The same study also demonstrated indirect pathways from motor competence to PA engagement through HRF, and vice versa, for both the boys and the girls (Jaakkola et al., 2019). This would suggest that HRF and PA have a reciprocal relationship, as first put forward by Stodden et al. (2008).

The relationship between FMS and components of HRF are also widely researched, with Stodden and colleagues (2014) proposing that the relationship is dynamic and strengthens with age. A recent review surmises the main findings (Cattuzzo et al., 2016), and reports substantial evidence supporting a positive association between FMS proficiency and cardiovascular endurance (CVE) (Barnett et al., 2008; Erwin & Castelli, 2008; Haga, 2008, 2009; Hands, 2008; Hardy et al., 2012; Stodden et al., 2008). CVE is the capacity of the cardiovascular and respiratory systems to participate in continuous strenuous exercise (Ortega et al., 2008). The health benefits attributed to CVE are well established, with increased CVE having a positive association with reducing the risk of cardiovascular disease, mental health issues and obesity (Ortega et al., 2008; Pate et al., 2012). Higher CVE and FMS proficiency have also been associated with higher academic performance in adolescents (Haapala, 2013). The review also reports an inverse association between FMS and body composition, i.e. the higher the FMS proficiency the better the body composition, with 27 of 33 studies demonstrating said association (Cattuzzo et al., 2016). Again, the benefits of a healthy weight status are numerous, with increased adiposity having clear links to chronic disease (Rizzo et al., 2007; Ruiz et al., 2009). While the relationship between FMS and all of the HRF components will be examined in greater detail later in this literature review, the evidence of a positive association is strong. Much of this evidence is, however, cross-sectional and only captures limited data of a particular age. At the very least, future cross-sectional research design should seek to examine the relationship across children to examine whether the nature of the relationship between FMS and HRF is dynamic as predicted by Stodden et al. (2008).

The benefits associated with FMS are evident and highlighted above. There is a growing body of research linking FMS to increased PA engagement (Barnett et al., 2009; Jaakkola & Washington, 2013; Lubans et al., 2010). The simple act of increasing PA has several associated health benefits and these are well established (Ortega et al., 2008; Ruiz et al., 2006a). This, combined with evidence of a positive relationship between FMS and CVE (Cattuzzo et al., 2016; Lubans et al., 2010), and an inverse relationship with body composition (Cattuzzo et al., 2016; Lubans et al., 2010), suggests that FMS can have a major role in promoting HRF. A thorough examination of HRF and the associated health outcomes, along with a more detailed examination of the relationships between HRF and FMS, is warranted.

2.3 Health Related Fitness

Introduction to Health Related Fitness

Health related fitness (HRF) is defined as a multidimensional construct made up of several components; namely, cardiovascular endurance (CVE), muscular strength (MS), muscular endurance (ME), flexibility and body composition (Caspersen et al., 1985). CVE is the capacity of the cardiovascular and respiratory systems to participate in continuous strenuous exercise (Ortega et al., 2008). MS is described as the muscular systems maximal production of force (Smith et al., 2014) , while ME is the ability of the muscular system to produce force over a period of time (Smith et al., 2014). MS and ME are often grouped together under the term muscular fitness (MF). Flexibility refers to the range of motion at a joint (Pate et al., 2012) and body composition is the physical make-up of the body (Caspersen et al., 1985).

Importance of Health Related Fitness

HRF has been established as a powerful indicator of health (Pate et al., 2012). With the exception of flexibility, the rest of the HRF components have been independently identified as factors that predict health outcomes throughout life (Ruiz et al., 2009). High levels of fitness in children, youth, and adults have a positive relationship with obesity, mental health, cardiovascular disease and bone health (Kvaavik, Klepp, Tell, Meyer, & Batty, 2009; Ortega et al., 2008). High levels of CVE in youth are associated with better cardiovascular health as an adult (Ruiz et al., 2009). In a review of studies examining the link between HRF and health outcomes, it was found that CVE levels in particular are related to cardiovascular disease risk factors, adiposity, and mental health (Ortega et al., 2008). Cardiometabolic disease risk factors include waist circumference, blood pressure, total triglycerides, cholesterol and blood glucose levels (Bailey, Boddy, Savory, Denton, & Kerr, 2012). A recent study, which analysed the relationship between these cardiometabolic disease risk factors and CVE in children and adolescence, showed the youths with higher CVE levels were at a significantly lower risk for cardiometabolic disease than their less fit counterparts (Bailey et al., 2012).

The association with body composition and health is strong, with increased adiposity having clear links to increased risks of chronic disease (Rizzo et al., 2007; Ruiz et al., 2009). Over the past three decades, the prevalence of overweight and obese children has increased worldwide (de Onis & Lobstein, 2010). This excess fat in children can bring a host of negative health implications, including insulin resistance, fatty liver disease and increased risk of hypertension. It is also known that those who are overweight or obese as children are more likely to be overweight or obese as an adult (Simmonds, Llewellyn, Owen, & Woolacott, 2016). As an adult, health risk factors such as cardiovascular disease and type-2 diabetes are highly associated with increased body mass (de Onis & Lobstein, 2010). An increasingly sedentary lifestyle can lead children to gain excess mass and the obvious solution seems to be engaging children in PA from a young age, however the research shows that it is not that simple. Many interventions directly targeting PA in children report that these programmes have shown a daily increase in children's PA levels of just four minutes (Metcalf et al., 2012). A review of international prevalence data shows that over 80% of adolescents don't meet the minimum guideline of one hour of moderate to vigorous intensity physical activity a day (MVPA) (Hallal et al., 2012), with the WHO reporting that one in five children are overweight or obese (World Health Organisation, Global Health Observatory, 2018). It is clear that reducing obesity in children should be considered a priority and all means in which this can be achieved should be explored.

There is evidence linking the benefits of MF with reduced risk of obesity (Smith et al., 2014), and cardiovascular disease (Grøntved et al., 2013; Janz, Dawson, & Mahoney, 2002). Moderate to high strength levels (MS) have been shown to be postively associated with insulin resistance (Benson et al., 2006), which is a precursor to diabetes. This finding was independent to CVE and suggests that MS may protect against high insulin insensitivity (Benson et al., 2006). There is also evidence to suggest that MS has a negative association with adiposity (Smith et al., 2014). A review of longitudinal studies found that increased MS as a child is inversely related to adiposity as an adult (Ruiz et al., 2009), with Grontved et al. (2015) reporting that MS in adolescents predicts waist circumference in early adulthood. ME is also linked with positive health benefits, with lower torso ME associated with a decreased mortality risk in both women and men (Katzmarzyk & Craig, 2002). ME of the torso contributes to the effective and efficient use of the upper and lower body limbs (Oliver, Adams-Blair, & Dougherty, 2010) and spinal column stability (Dennison, Straus, Mellits, & Charney, 1988), which allow the optimal function of the body in engaging in a healthy, active lifestyle. Several reviews have demonstrated the importance of MF development as a child in order to maintain good health in later life (Janz et al., 2002; Ruiz et al., 2009).

There is little to suggest flexibility has any significant relationship with positive health outcomes (Casonatto et al., 2016; Stodden et al., 2017). Casonatto and colleagues (2016) found that flexibility had no correlation with adiposity in Brazilian children. A review of the literature showed that only one study showed a positive link between flexibility and a positive health outcome, whereas six others did not find any significant outcomes (Stodden, Sacko, & Nesbitt, 2017). A recent study has questioned flexibility's role in the HRF construct, reporting that it does not feed into an effective model for measuring HRF (Britton et al., 2019*, in press*).

While developing HRF obviously requires PA engagement, as one cannot expect to increase their fitness or strength through inactivity, it is interesting to note that positive health outcomes seem to have a greater association with increases in HRF than increases in PA alone (Janz et al., 2002; Bailey et al., 2012). Keeping this in mind, it seems important that developing HRF be prioritised in children in order to achieve positive health outcomes. Knowledge of the current levels of HRF in children and youth would allow for interventions targeting the same. In order to know the current levels of HRF, the means of measuring HRF must be investigated.

Health Related Fitness Measurement

Several HRF test batteries have been developed to assess and compare fitness levels. There are two which have been used widely in research, particularly with children and adolescents, namely the FITNESSGRAM (The Cooper Institute, 2001) and the EUROFIT (Council of Europe, 1983). These are both field based assessment batteries and they contain several of the same measures of HRF components (see Table 2.1). FITNESSGRAM, developed in the USA, measures all five components of HRF and provides normative scores based on age (Welk, Going, Morrow, & Meredith, 2011). The creators of the FITNESSGRAM, the Cooper Institute, used data from the national NHANES study which allowed them to develop thresholds based on age which they termed healthy fitness zones (HFZ). Any child or teen who fell below this threshold upon assessment was deemed to be at risk of poor health (Meredith & Welk, 2007). The FITNESSGRAM, or components of it, has been used extensively in measuring HRF worldwide (Ortega et al., 2011; Stodden et al., 2014; Khodaverdi et al., 2015; Rodrigues et al., 2016). The European developed EUROFIT test battery has also been used widely to measure HRF in research (Ortega et al., 2005; Carraro, Scarpa, & Ventura, 2010; Bronikowski & Bronikowska, 2011; Vedul-Kjelsås et al., 2012a; Gísladóttir et al., 2014). The EUROFIT does not provide age based normative data, however a review of HRF levels across Europe does provide normative values for European adolescents (Ortega et al., 2011). The review looked at studies which had used similar protocols described in the EUROFIT (Council of Europe, 1983) and has allowed HRF researchers a cohort norm for comparative purposes (Ortega et al., 2011). A large amount of research measuring HRF in children and adolescents have chosen to use components of both the FITNESSGRAM and EUROFIT (Ortega et al., 2011). While these are the most common, there are other assessments which are more suitable specifically for children, some of which will be examined below.

One of the most widely used HRF assessments cited in the literature is the 20m PACER test (Ortega et al., 2008). This test was developed to calculate VO_{2max} based on age and the final score achieved (Léger, Mercier, Gadoury, & Lambert, 1988). VO_{2max} is the maximal oxygen consumption available to a participant and is widely used in measuring CVE (Ruiz et al., 2006). While the gold standard of measurement for VO_{2max} takes place in a laboratory through exercise to exhaustion (Pate et al., 2012), this is an impractical method for a large cohort due to the expense, time needed, and the expertise and equipment required (Grant et al., 1995). In addition, the 20m PACER was found to be a valid tool to assess VO_{2max} in comparison to some of the gold standard laboratory based assessments, such as the incremental treadmill test (Ramsbottom, Brewer, & Williams, 1988). While the research of Ramsbottom et al. (1988) dealt with a cohort of adults, the FITNESSGRAM has produced reliable, age-relevant, healthy ranges of CVE throughout children and adolescence (Welk et al., 2011). The EUROFIT also utilises the 20m PACER and research has also been proven reliable in the children and adolescent cohort (Morrow, Martin, & Jackson, 2010). In the context of working with large groups, the 20m PACER test is seen as a valid alternative as a field based assessment (Ortega et al., 2005). The test itself requires little set up. Participants run back and forth between two lines spaced 20m apart in time with an audible cue. If a participant fails to reach the line in time with the cue on two consecutive occasions, then they are deemed to have finished the test. The amount of shuttles completed are then used to calculate the VO_{2max} of each participant using formulas described by Leger et al. (1984).

There are several options to measure ME, some of which are more practical than others for use in field based testing. Measuring ME using push-ups and curl-ups are easier to administer than tests such as pull-ups or flexed arm hangs due to the equipment needed (Council of Europe, 1983; The Cooper Institute, 2001). These assessments however may not be best suited to children as a score of zero is possible, and this may be disheartening to a child (Boyer et al., 2013). Muscle endurance can also be measured through an isometric plank hold (Francis et al., 2015). This test is thought to be particularly useful for younger children (8 – 12 years age) as it has shown that all achieve a higher than zero score (Boyer et al., 2013), in contrast to curl-ups or push ups reported in other studies (Meredith & Welk, 2010). The protocol required participants to hold a static prone position with just their forearms and toes touching the floor until failure with the score being recorded to the nearest second (Boyer et al., 2013).

Table 2.1 Tests included in the FITNESSGRAM (The Cooper Institute, 2001) and EUROFIT (Council of Europe, 1983) for each HRF component

	FITNESSGRAM	EUROFIT
CVE Measures		
1-mile run	✓	
20m PACER (shuttle run)	✓	✓
1mile walk	✓	
PWC170 (cycle ergometer)		✓
6min run test		✓
ME Measures		
Abdominal curl-up	✓	✓
90◦ push-up	✓	
Modified pull-up	✓	
Pull-up	✓	✓
Flexed arm hang	✓	✓
MS Measures		
Trunk extension/lift test	✓	✓
Standing broad jump		✓
Vertical jump		✓
Flexibility Measures		
Back-saver sit-and-reach	✓	
Sit-and-reach (double leg)		✓
Body Composition Measures		
Skinfold thickness	✓	
%BF via bioelectrical impedance	✓	
BMI	✓	

Again, the FITNESSGRAM and EUROFIT batteries provide several options for measuring MS. While both the vertical and standing broad jump are both valid and reliable measures (Council of Europe, 1983; The Cooper Institute, 2001), assessing MS through hand grip strength with a hand dynamometer has been commonly used throughout HRF research involving children and youth (Ruiz et al., 2006). After adjusting the dynamometer to the subjects required grip span (Ruiz et al., 2006), grip strength is assessed while participants are in a standing position with their arm fully extended. Both left and right hands are measured to the nearest 0.1kg, with the best scores on each being averaged to provide a total hand grip strength score (Ortega et al., 2008; Ruiz et al., 2006).

The majority of studies in which flexibility is measured in children or youths employs the sit-and-reach test, or the version known as the back saver sit-and-reach (Ortega et al., 2011). While both versions measure hamstring flexibility, the back saver sit-and-reach assesses one leg at a time and can reduce the risk of injury or overstretching to the back when compared to the sit-and-reach version (Ruiz et al., 2006). The protocol for the back saver allows for both legs to be measured separately and this can highlight any asymmetries in hamstring flexibility (Ruiz et al., 2006). Flexibility is measured to the nearest centimetre, with both sides assessed and the average score is reported. While the sit-and-reach assessment only measures hamstring flexibility, there are those who argue that flexibility should be assessed in several different areas of the body due to flexibility being unique to each individual joint (Castro-Piñero et al., 2013). Other tests have been used in research, such as the back-scratch test to measure shoulder flexibility (Castro-Piñero *et al.*, 2013; Plowman and Mahar, 2013). However, a substantial amount of studies assess flexibility using either of the sit-and-reach tools, so while these are useful for comparative purposes, it should be noted that they are limited in that they are site specific (Ortega et al., 2011; Ruiz et al., 2006).

The inclusion of various forms of body composition measures is perhaps the most widely measured of all the HRF components. Body mass index (BMI) is the most frequently used in studies using large numbers (de Onis & Lobstein, 2010; Woods et al., 2010; May, Kuklina, & Yoon, 2012; Heinen, Murrin, Daly, & Brien, 2014; Ogden, Carroll, Fryar, & Flegal, 2015). BMI assesses a persons' body composition through measuring their body mass in relation to their height (de Onis & Lobstein, 2010). This method is widely used due to its ease of administration, cost effectiveness and its relatively non-invasive protocols (Gupta, Balasekaran, Govindaswany, Hwa, & Shun, 2011; Loenneke et al., 2013). Height and mass is measured using a stadiometer and a scale in accordance with standardised procedures (Meredith & Welk, 2010). Height was measured to the nearest 0.1cm and mass to the nearest 0.5kg, which allowed BMI to be calculated (BMI= weight (kg)/height (m^2)). The World Health Organisation has developed age and sex based normative figures for BMI in children and these contain thresholds which collate individuals into: severely thin, thin, healthy, overweight and obese categories (de Onis & Lobstein, 2010). While these thresholds, and the frequency of BMI measurement, can allow for comparative analyses, there are limitations involved with using BMI. Savva et al. (2000) reports that BMI does not predict cardiovascular disease risk in children as well as waist circumference, another commonly used body composition measure, with Mitchell et al. (2012) recommending that, when working with youths, another form of body composition assessment be used in conjunction with BMI.

Waist circumference has a strong association with cardiovascular and metabolic disease risk factors (Freedman, Serdula, Srinivasa, & Berenson, 1999; Savva et al., 2000; Shen et al., 2006), and is commonly used as a measurement of abdominal fat (Després, 2012; Klein et al., 2007). Waist circumference is measured to the nearest 0.1cm when participants are at minimal respiration and is taken at the highest point of the iliac crest (Gillum, 1999). Waist circumference is reported to be a significantly stronger predictor of cardiovascular disease risk than either BMI or another body composition measure, waist-hip ratio (Savva et al., 2000). It must be noted, however, that waist circumference may not be as useful as a predictor in young children as body fat centralisation does not take place until puberty (Cameron, Jones, Griffiths, Norris, & Pettifor, 2009). Potential gender differences should also be considered in this regard, as females generally progress into puberty at an earlier age than their male counterparts (Malina, 2014). Other options for body composition measurement include skinfold measurement and bioelectrical impedance analysis (BIA). Measuring skinfold thickness requires training to become proficient and is used to assess body fat percentage (Loenneke et al., 2013). It is, however, an invasive technique which involves an assessor pinching skin at various points of the body and as such may not be suitable for use with children. BIA aims to give a more detailed image of body composition, with percentages of lean mass, body fat and bone density reported (Gupta et al., 2011). The equipment required is expensive however, and reliability and validity between varying models is not established, making it difficult to use for comparative purposes. When working with large groups, BMI and waist circumference seem to be the simplest, most cost effective and least invasive methods to measure body composition.

Levels of Health Related Fitness

Tomkinson et al. (2018), in their recent systematic review of HRF in European children and adolescents, reported that 83% of females and 78% of males were judged to have healthy CVE levels (n = 2,799,165, age range 9-17 years). Another large study made up of adolescents from various European cities (n = 3,428, age range 12.5-17.5 years), found lower levels of CVE present, with 61% of the boys and 58% of the girls classified as having healthy CVE status (Ortega et al., 2011). Portuguese children and teens (n = 22,048, age range 10-18 years) had similar CVE levels (61.1%) and interestingly, in the 10-14 year old age bracket, significantly more females reported healthy CVE than males (Santos et al., 2014). Conversely, the males had significantly higher CVE levels in the 15-18 year old bracket (Santos et al., 2014). Results from the aforementioned NHANES study in the USA, which focused on 12-15 year olds, showed that only 42.3% had a healthy CVE status, which is low compared to the findings emanating in Europe (Beals et al., 2016). This research reported males achieving greater levels of CVE (50.4%) compared to females (33.9%) (Beals et al., 2016). The development of CVE tends to increase with age, which VO_{2max} increasing throughout childhood and into adolescence (Janz et al., 2000; Kemper et al., 2013). In males, this increase lasts throughout adolescence, however the research reports females frequently peak their VO_{2max} development by age 14 (Janz et al., 2000; Kemper et al., 2013). These results mirror findings from reviews suggesting that CVE increases with age from childhood throughout the teenage years (Ortega et al., 2011; Santos et al., 2014). A more recent review, however, found that the percentage of children and youths achieving a healthy CVE status annually decreased from nine years of age (Tomkinson et al., 2018).

Males tend to exhibit significantly higher levels of HRF, with one systematic review reporting European males outperforming females in CVE, MS and ME (Tomkinson et al., 2018). Flexibility is the exception, with females achieving higher levels (Tomkinson et al., 2018), and these findings are corroborated by several studies examining HRF in European children (Ortega et al., 2011; Santos et al., 2014). These gender differences increase with age, with males developing the CVE, MS and ME components faster than their female peers (Tomkinson et al., 2018). Malina and Katzmarzyk (2006) state that most of these HRF components generally show a linear improvement throughout childhood, until the age of 13 where males accelerate in their development in comparison to their female counterparts. This gender difference can be attributed to physiological change which occurs with puberty, with males increased testosterone production enhancing endurance and strength development (Malina, 2014).

As the WHO normative thresholds for BMI are widely used (de Onis & Lobstein, 2010), body composition, in the form of BMI, can be compared widely throughout research. According to the WHO's Global Health Observatory, 18% of children and adolescents globally were overweight or obese in 2016, and they have identified childhood obesity as "one of the most serious public health challenges of the 21st century". Ireland is not immune to this crisis, with the CSPPA report showing that one in four children are overweight or obese (Woods et al., 2018). Given the association obesity has with noncommunicable diseases such as cardiovascular disease (Heinen et al., 2014), it seems that efforts should be made to ensure a healthy weight status amongst Irish children.

The CSPPA study found 84% of the Irish participants achieved a healthy CVE status (Woods et al., 2018). Irish research has consistently reported higher levels of CVE than those found in Europe and the USA (Beals et al., 2016; Ortega et al., 2011; Santos et al., 2014), with Belton et al. (2018) findings showing 77.6% of teens with healthy CVE status. Irish data does reflect the gender differences in HRF outlined previously, with females showing significantly lower CVE levels than males (Irish Life Schools Fitness Challenge, 2018). The Irish Life Schools Fitness Challenge (2018) has shown that this trend continues through the teenage years (n = 14,804, 56% female, age 13-16 years) and the gender gap in CVE levels increases from 32% to 42% over four years. There is a scarcity of research examining HRF in Irish children. It seems prudent that future research should both assess and track HRF levels in Ireland, as the health benefits associated with the HRF components are extensive and well established (Ortega et al., 2011; Pate et al., 2012; Ruiz et al., 2006a). Some researchers propose that HRF and FMS have a dynamic relationship and interact to influence a child's PA levels (Stodden et al., 2008). The link between FMS and PA has already been outlined, as has the fact that increasing PA will automatically impact on HRF through the simple act of moving more often. Any increase in the HRF components will see individuals benefit from the positive health outcomes as discussed above. In this instance, a closer look at the relationship between HRF and FMS is warranted.

2.4 The Relationship between Fundamental Movement Skills and Health Related Fitness

Research investigating the relationship between FMS and HRF has consistently shown positive associations (Cattuzzo et al., 2016; Lubans et al., 2010). When looking at the relationship between FMS and the HRF components, results demonstrate strong evidence of positive associations between FMS and CVE (Barnett et al., 2008), FMS and MS (Hands, Larkin, Parker, Straker, & Perry, 2009), FMS and ME (Erwin & Castelli, 2008), and an inverse association with body composition (Lopes et al., 2012). Notably, the associations between FMS and the HRF components appears to be similar for both males and females (Cattuzzo et al., 2016). However, studies generally choose to measure just one of the HRF components, most commonly CVE, as a proxy for the HRF construct (Cattuzzo et al., 2016).

Strong evidence exists of a positive association between FMS and both MS and ME, with studies measuring MS through a hand dynamometer showing a positive association with FMS (Stodden et al., 2014; Vandendriessche et al., 2012), and others used a standing long jump to assess MS showing a significant positive relationship with FMS (Gísladóttir et al., 2014; Haga, 2009; Hands, 2008; Vandendriessche et al., 2012). In ME, studies used a variety of both abdominal and upper body endurance tests (Cattuzzo et al., 2016; Lubans et al., 2010), and the findings reflected the MS results, with substantial evidence for a positive association between ME and FMS. While all these studies show significant findings, there has been relatively little literature published on the strength of these relationships across a wide age range, particularly in children. Stodden et al. (2008) hypothesised that these relationships are dynamic and future research should seek to explore these relationships across time to test this proposal.

A recent systematic review, examining the relationship between FMS and body composition, reports that 82% of these studies reported a significant inverse relationship between FMS and body composition (Cattuzzo et al., 2016). A previous review (Lubans et al., 2010), backs this up with six of the nine studies showing a significant inverse relationship between body composition and FMS. Lopes et al. (2012) reports that FMS demonstrates an inverse relationship with body composition, and that this relationship strengthened through childhood. This suggest that the association between FMS and body composition may be dynamic and change as a child gets older (Lopes et al., 2012). While there appears to be substantial evidence supporting a strong relationship between the two, it must be noted that some studies find no relationship between BMI and FMS (Hands, 2008; Hume et al., 2008; Logan et al., 2013). As discussed in a previous section, it may be prudent to take another measure of body composition along with BMI to ensure accurate results (Mitchell et al., 2013).

While the evidence seems to be clear for associations between FMS and body composition, MS and ME, it is inconclusive when looking at the relationship with flexibility and FMS. The majority of studies measure flexibility using the sit-and-reach test, and some results show positive associations with motor competence (Hands et al., 2009a; Pereira et al., 2011; Vandendriessche et al., 2012). Others, however do not show any significant findings when examining the relationship between the two (Castelli & Valley, 2007). These conflicting findings suggest the evidence is inconclusive and flexibility may not have a significant relationship with FMS (Cattuzzo et al., 2016), although future research should seek to examine this further.

When looking at the relationship between FMS and CVE, there is substantial evidence to support a strong positive association (Cattuzzo et al., 2016; Lubans et al., 2010). According to Haga et al. (2009), children who demonstrate poor FMS proficiency are more likely to have poor CVE levels. Several other studies report similar results, highlighting the positive correlation between FMS and CVE (Barnett et al., 2008; Hands et al., 2009; Hardy et al., 2012; Okely et al., 2001). It has been suggested that the differences regarding CVE levels stay relatively constant between the low and high motor competence groups (Haga, 2009). If this is the case, having poor FMS proficiency as a child may have implications for their future fitness levels. Barnett et al. (2008) looked at this relationship longitudinally and found that a child's object control skills proficiency was a predictive factor of their CVE as an adolescent six years later. Those with a higher object control skill level as children were 26% more likely to have higher CVE levels (Barnett et al., 2008). Another longitudinal study looked at the relationship between FMS and CVE over five years and found that FMS competency directly related to increased CVE levels (Hands, 2008).

Table 2.2 Description of studies examining the relationship between FMS and HRF (adapted from Cattuzzo et al., 2016)

STUDY / LOCATION	DESIGN; SAMPLE; AGE;	MEASURE OF FMS	MEASURE OF HRF	STATISTICS	MAIN RESULTS / [STRENGTH OF CORRELATION]
D'HONDT ET AL. (2009) / BELGIUM	*Cross-sectional; 117 children, 5-10 yrs*	*Product; MABC*	*BMI*	*ANOVA and bivariate correlations; MABC total score and BMI-z scores: r=.34; balance and BMI-z score: r= .46; ball skills and BMI-z score: r= .20*	*Childhood obesity inversely associated with MC/ [low]*
PEREIRA ET AL. (2011) / PORTUGAL	*Cross-sectional; 3699 children, 6-10 yrs*	*Product; KTK*	*1-mile run/walk; curl-up; 90° push-ups; and trunk-lift (from FITNESSGRAM)*	*Logistic regression (adjusted for sex, age, PA, OW and obesity); OR= 1.014 -1.018 for pass rates of curl-ups, push-ups, trunk-lift and mile run*	*A better MC was associated with a higher probability of being fit in all tests;*
OKELY, BOOTH & CHEY (2004) / AUSTRALIA	*Cross-sectional; 4363 children/adolescents, grades 2 (7-8 yrs), 4 (9-10 yrs), 6 (11-12 yrs), 8 and 10 (13-16 yrs)*	*Process; process-oriented checklists run, vertical jump, catch, overhand throw, strike, kick*	*BMI; Waist circumference*	*Logistic regression and linear regression (both adjusted for age, socioeconomic status, cultural background and rurality); β= -.29 (boys grade 4), β= -.32 (boys grade 6); β= -.14 (boys grade 8); β= -.25 (girls grade 4), β= -.17 (girls grade 6); β= -.10 (girls grade 8); β= -.22 (girls grade 10). MC and waist circumference: β= -.12 (boys grade 4), β= -.14(boys grade 6); β = -.07 (boys grade 8); β = -.12 (girls grade 4), β= -.08 (girls grade 6); β= -.10 (girls grade 10)*	*Non-OW boys and girls were two to four times more likely to be advanced in MC than overweight pairs (adjusted for age, socioeconomic status, cultural background and rurality)*
CASTELLI & VALLEY (2007) / US	*Cross-sectional; 230 children/adolescents, 7-12 yrs*	*Process; SCPEAP*	*FITNESSGRAM;*	*Bivariate correlations; SCPEAP and overall measure of HRPF: r= .36; SCPEAP and PACER: r= .57; SCPEAP and curl-ups: r= .39; SCPEAP and push-ups: r= .36*	*Positive association between MC and overall measure of HRPF; between MC and cardiorespiratory fitness [moderate]; strength and endurance muscular; [low]; BMI and flexibility not associated with MC/ [not significant]*
ERWIN & CASTELLI (2008) / US	*Cross-sectional; 180 children/adolescents, 9-12 yrs*	*Process; SCPEAP*	*FITNESSGRAM*	*Bivariate correlations; SCPEAP and overall measure of HRPF: r= .32*	*MC positively associated with overall measure of HRPF / [low]*
D'HONDT ET AL. (2011) /BELGIUM	*Cross-sectional; 954 children/adolescents ,5-12 yrs;*	*Product; KTK*	*BMI*	*ANCOVA (adjusted for AHPV) and chi-square tests; Main effect: χ^2= 120.9; the relationship between MC and BMI was distinguished by age groups (χ^2 values between 14.49 and 61.85)*	*Lower MC in OW and obese vs. normal weight children. BMI-related differences in MC were more pronounced as children belonged to an older age group (Chi-square)*
VANDENDRIESSCHE ET AL. (2011) / BELGIUM	*Cross-sectional; 613 children/adolescents, 7, 9 and 11 yrs*	*Product; KTK*	*EUROFIT; BOTMP-2*	*Canonical correlation analysis; MC and morphology: F= 6.76 to 13.42; MC and fitness: F= 5.45 to 7.88*	*Positive canonical association between morphology, fitness and MC; inverse association between weight and %fat*
HARDY ET AL. (2012) / AUSTRALIA	*Cross-sectional; 6917, children/adolescents, grades 2 (7-8 yrs), 4 (9-10 yrs) and 6 (11-12 yrs), adolescents grades 8 and 10 (13-16 yrs)*	*Process; Get Skilled: Get Active: sprint run, vertical jump, side gallop, leap, catch, overarm throw, and kick*	*BMI; PACER*	*Logistic regression; Cardiorespiratory fitness: Low MC in OC skills and low PACER. Boys: OR= 21.03 (9-10 yrs); OR= 4.94 (11-12 yrs); OR= 3.20 (13-16 yrs); Girls: OR= 1.92 (11-12 yrs); OR= 2.60 (13-16 yrs). Low MC in LOC skills and low PACER. Boys: OR= 14.78 (9-10 yrs); OR= 6.91 (11-12 yrs); OR= 7.72 (13-16 yrs); Girls: OR= 5.87 (11-12 yrs); OR= 3.01 (13-16 yrs). Overweight /obesity: Low MC in OC skils and overweight /obesity. Boys:*	*Low MC associated with low cardiorespiratory fitness; There was a pattern of low MC in CO and LOC skills and overweight /obesity*

				OR= 2.22 (9-10 yrs); Low MC in LOC skils and overweight /obesity. Boys: OR= 2.65 (9-10 yrs); Girls: OR= 2.83 (9-10 yrs)	
LOPES, STODDEN, BIANCHI ET AL. (2012) PORTUGAL	*Cross-sectional; 7175 children/ adolescents, 6-14 yrs*	*Product; KTK*	*BMI*	*Kruskal–Wallis test and bivariate correlation; MC and body composition: r= -.16* to -.30 (6-10 yrs); r= -.26 to -.49 (11- 13 yrs)*	*Difference between groups: healthy weight group performed better than OW and obese groups; Inverse association between MC and BMI in children [low] and adolescents [low to moderate]*
STODDEN ET AL. (2014) US	*Cross-sectional; 476 children/adolescents, 4 –13 yrs); subjects classified in five age groups for data analysis*	*Product in individual skills: maximum speed for throwing (using tennis balls) and kicking (20cm diameter playground balls) and maximum jump distance/height (standing long jump).*	*Overall measure of HRPF from FITNESSGRAM protocol (curl-ups, pushups and PACER). Also was examined grip strength using a hand grip dynamometer*	*ANCOVA (adjusted for age), bivariate correlation, hierarchical linear regression; Kicking MC and overall measure of HRPF: r=.38 (4-5 yrs); r=.37 (6-7 yrs); r=.42 (8-9 yrs); r=.44 (10-11 yrs); r=.59 (12-13 yrs); Jumping MC and overall measure of HRPF: r= .55 (4-5 yrs); r= .34 (10-11 yrs); Throwing MC and overall measure of HRPF: r= .39 (6-7 yrs); r= .42 (8-9 yrs); r= .47 (10-11 yrs); r= .65 (12-13 yrs)*	*Positive association between MC and overall measure of HRPF in children [low to moderate] and adolescents [low to moderately high]*
HANDS (2009) / AUSTRALIA	*Longitudinal; 38 children followed by 5 years (baseline: 5-7 yrs; 10-12 yrs)*	*Product; SIS*	*BMI; PACER; overhand throw; standing broad jump*	*ANOVA; MC (high vs low) and PACER: F= 22.32; MC (high vs low) and 50-m run: F= 54.57; MC (high vs low) and overhand throw: F= 13.78; MC (high vs low) and standing broad jump: F= 45.08; MC (high vs low) and balance: F= 71.36*	*Difference between groups: children with high MC were better than low MC for all measures except for BMI*
BARNETT, VAN BEURDEN, MORGAN, BROOKS, BEARD (2008) / AUSTRALIA	*Longitudinal; 928 children/adolescents (7-11yrs) evaluated in 2000; 244 adolescents evaluated after 7 years*	*Process; Get Skilled Get Active: kick, catch, throw, hop, side gallop, vertical jump*	*PACER*	*Linear regression (adjusted for gender); MC and cardiorespiratory fitness:* *OC proficiency in childhood was associated with adolescent cardiorespiratory fitness (r= .51)*	*OC in childhood positively associated with cardiorespiratory fitness in adolescence / [moderate]*
HAGA (2009) / NORWAY	*Longitudinal; 67 children/adolescents 9-10 yrs accompanied for 32 months (final sample= 58);*	*Product; MABC*	*TPF*	*ANOVA; March/2004, MABC and TPF total score: r = -.58 (n=67); November/2006: MABC and TPF total score: r= -.51 (n=58)*	*Difference between groups: low MC group improved less in cardiorespiratory fitness, strength and endurance muscular than high MC group; positive association between MC and TFP total score in both data collection / [moderate]*

While most studies use one HRF component as a proxy for overall HRF, others choose to merge several components of HRF together as a composite score (Erwin & Castelli, 2008; Stodden et al., 2014). Stodden and colleagues (2014) measured CVE, ME and MS and combined them to give participants an overall HRF score, which they then used to analyse the relationship with FMS proficiency. The findings suggest that the relationship between FMS and HRF is dynamic and changes across age, with a strengthening in association between object control skills and HRF as the participants got older (Stodden et al., 2014). While this study is the first to demonstrate that the relationship between object control skills and HRF strengthens across age in both boys and girls, it is not without its limitations. Only three FMS skills were measured: throw, kick and jump, and these were product based assessments (Stodden et al., 2014). This narrow range of FMS assessments, containing only one locomotor skill, may not give an accurate representation of participants true FMS proficiency. While there is a great degree of merit in looking at the FMS vs. HRF relationship across age, the author believes that future research should include a broader examination of FMS skills which may give a more accurate picture of any association.

Stodden and colleagues suggest that the relationship between FMS and HRF are dynamic and strengthen with age, implying that the development of FMS may be a "*causal mechanism to promote either positive or negative trajectories of HRF as well as physical activity and body composition status across time*" (2008, p.232). The positive association between FMS and HRF is evident from the evidence presented above (Cattuzzo et al., 2016; Lubans et al., 2010), and the research reports associations are similar across gender (Cattuzzo et al., 2016). The links with positive health outcomes and most of the HRF components is clear (Pate et al., 2012), and the importance of improving HRF levels across childhood, and the methods to do so, should not be overlooked. The literature reports that increased levels of FMS development leads to increased PA participation (Robinson et al., 2015), suggesting that increasing FMS proficiency may affect the HRF components (Cattuzzo et al., 2016; Stodden et al., 2014). Knowing that there is a trend showing children and adolescents to demonstrate low levels of HRF and poor FMS proficiency (Belton et al., 2014; Bolger et al., 2018; Kelly et al., 2018; O'Brien et al., 2016), it seems prudent that future research seeks to examine the relationship between HRF and FMS further.

2.5 School Based Interventions

Findings from over 120 countries report 80.3% of 13-15 year olds don't meet the minimum daily guidelines of one hours moderate to vigorous physical activity (MVPA) (Hallal et al., 2012). The findings across these countries are consistent in reporting girls being less active than boys (Hallal et al., 2012). Troiano and colleagues (2008) show the decline in MVPA from childhood into adolescence in the USA, with 42% of children accumulating the required 60 minutes per day, and just 8% of adolescents achieving this goal. Ireland reflects similar findings, with 19% of Irish children, and just 12% of adolescents meeting the daily activity requirements recommended by the Department of Health and Children (Woods et al., 2010). With the negative health effects associated with physical inactivity, such as increased risks of cardiovascular disease, obesity, and bone health (Pate et al., 2012), it seems clear that intervention is needed. The WHO has identified the need for interventions targeting PA participation amongst children and youth (World Health Organisation, social determinants of health and well-being among young people, 2012) as the health benefits are well established (Van Der Horst, Paw, Twisk, & Van Mechelen, 2007). The United Nations have produced 17 sustainable development goals as a part of a "*blueprint to achieve a better and more sustainable future for all*", and the third goal is 'good health and well-being' (Transforming our world: The 2030 agenda for sustainable development, 2015). With such prominence put on positive health outcomes, it is alarming to see the lack of progress. While there have been numerous initiatives and interventions aimed at increasing PA, particularly in the adolescent population (Beets et al., 2016), these seem to be failing to impact the low levels of PA in youth on a large scale. It is evident that a fresh approach is needed (Metcalf et al., 2012).

There is a growing body of research suggesting that developing FMS proficiency in children can lead to increased PA engagement in later life (Barnett et al., 2009; Robinson et al., 2015). Research also suggests that developing motor competence is positively associated with improved HRF (Cattuzzo et al., 2016; Lubans et al., 2010). Given the substantial evidence linking HRF and PA to positive health outcomes (Cattuzzo et al., 2016; Pate et al., 2012), it is evident that developing FMS as a strategy to help improve both HRF and PA in youth may be worthwhile.

Global trends show poor levels of FMS proficiency among children (Barnett et al., 2010; Kelly et al., 2018; Lubans et al., 2010). If this trend is allowed continue throughout childhood, it may result in young people entering into adolescence with poor FMS proficiency, and may consequently have a negative impact on their HRF and PA participation (Barnett et al., 2009; Cattuzzo et al., 2016b; Jaakkola et al., 2019; O'Brien et al., 2016). From an Irish perspective, there is research showing poor levels of FMS proficiency in children (Kelly et al., 2018; Farmer et al., 2017; Bolger et al., 2018) and adolescents (O'Brien et al., 2016b), alongside low levels of perceived competence in these FMS (McGrane et al., 2016). This low actual skill level, combined with a poor perception of skill performance, is hypothesised by Stodden and colleagues (2008, p.232) to send adolescents into a "*negative spiral of disengagement in PA*". The need for intervention to develop FMS in children, and promote "*a positive spiral of engagement in PA*" is warranted (Stodden et al., 2008, p.232).

The school environment has been singled out as a key opportunity in which to stage an intervention to increase FMS (Khambalia, Dickinson, Hardy, Gill, & Baur, 2012; O'Brien et al., 2013; Salmon, Booth, Phongsavan, Murphy, & Timperio, 2007). There are several studies which support the efficacy of school-based interventions to increase FMS (Belton et al., 2014; Lai et al., 2014; O' Brien et al., 2013; Van Beurden et al., 2003). The school setting provides a particularly salient opportunity for interventions that target children's FMS development (McKenzie & Lounsbery, 2014; McKenzie & Lounsbery, 2014b), and the school environment, if effective, should be fully inclusive of all individuals regardless of any socioeconomic or racial differences (Cavanagh, Macfarlane, A., Glynn, & Macfarlane, S., 2012). The PE lessons within schools provide ample opportunity to intervene (McKenzie et al., 2009). The difficulty often at primary level however, is that there may be no specialised PE teacher to deliver such targeted interventions. While some countries, such as Belgium, Greece, Spain and Poland, employ specialist PE teachers at primary school level, many, including Ireland, engage generalist teachers at primary level (Physical Education and Sport at School in Europe, Eurydice Report, 2013). This is just one of the many components that must be considered when planning effective interventions. Timperio et al. (2004) maintains that in order to achieve long term positive behavioural change towards PA, a multi-component approach should be taken in schools.

Components of Interventions

Several reviews of school based interventions targeting PA provide evidence of the effective strategies or components demonstrated in such interventions (Kriemler et al., 2011; Murillo Pardo et al., 2013; Salmon et al., 2007; Timperio et al., 2004). These reviews maintain that the more effective interventions involved multiple components and were not solely limited to what can be achieved in a PE lesson. Timperio et al. (2004) describe the more effective strategies to be those which incorporated a whole school approach, rather than a solely curriculum focused approach. The effective approaches include policy, curriculum and environmental strategies (Timperio et al., 2004). Another review of interventions targeting PA engagement in children found that the inclusion of a school break component, alongside a PE component, generated more success than interventions that did not include a break component (Salmon et al., 2007). This strategy has been adopted by numerous researchers who have developed interventions to increase the amount of activity achieved by children during break time in school (Loucaides, Jago, & Charalambous, 2009; Sutherland et al., 2016).

There is also substantial evidence to support the inclusion of a community or family component into the whole school approach (Belton et al., 2014; De Meij et al., 2010; Murillo Pardo et al., 2013). A review of school based interventions which included a community or family component were found to have a positive effect on increased PA participation (Van Sluijs, McMinn, & Griffin, 2007). The Youth Physical Activity Towards Health (Y-PATH) is one such successful intervention program which included a family component (alongside a PE curricular and whole-of-school component), through a parent/guardian information evening and website access which contained all the resources used in the intervention (O'Brien et al., 2013). Acker et al. (2011) also propose the inclusion of a community component into effective interventions. Specifically, they suggest that community organisations could be involved in school programs to facilitate the provision of activities that are attractive to the students (Acker et al., 2011). Another component which has gained traction in recent years is the inclusion of active classrooms as part of a whole school approach (Goh et al., 2014; Martin & Murtagh, 2015). While schools are targeted as an ideal environment to increase PA, the very nature of the classroom promotes sedentary behaviour with long periods of prolonged sitting (Holt et al., 2013). The primary school curriculum is ideal for incorporating PA and studies have shown that integrating PA into academic content improves children's PA levels during the school day (Donnelly et al., 2009; Bartholomew et al., 2011; Erwin et al., 2011). The research around school based interventions is clear and multi-component interventions are proven to be more effective, although the results do not always result in the behavioural changes that the researchers intended (Beets et al., 2016). Notwithstanding the above studies, research does frequently report the small effect size that many PA interventions have, with a recent review stating that programmes only have an average increase of approximately four minutes on children's overall daily activity levels (Metcalf et al., 2012). While the research supports the multi-component nature of these interventions, correlates of PA should also be considered as components for inclusion in any future interventions. As previously discussed, FMS development in children has been suggested to lead to increased PA participation in adolescence (Barnett et al., 2009).

FMS proficiency facilitates the acquisition of more complex movements (Gallahue & Ozmun, 2006) and furthermore, without these basic skills, children may be unwilling to partake in activities in which more advanced skills are required (Seefeldt, 1980; De Meester et al., 2016). It is therefore important to place a strong emphasis on skill development in school, particularly during PE (Stodden et al., 2008), knowing that FMS are the building blocks of future sport and PA engagement (Gallahue & Ozmun, 2006). The individual's perception of their ability to perform the FMS is also reported to be related to PA (Baker & Davison, 2011; Crocker et al., 2000; Davison, Schmalz, & Down, 2010; De Meester et al., 2016; Raudsepp, Liblik, & Hannus, 2002; Zhang, Thomas, & Weiller, 2015), as younger children who demonstrate poor skills may perceive themselves to be less skilled than their peers (Goodway & Rudisill, 1997; Weiss & Amorose, 2005). This perception could result in a lack of engagement in PA, due to children being too self-conscious to partake in activities requiring skills in which they perceive themselves to be poor (Horn & Weiss, 1991; Weiss & Amorose, 2005). The evidence suggests that any intervention in primary school aged children should have a strong focus on FMS in order to equip children with the confidence and basic skills needed to partake in PA throughout the life course (Stodden et al., 2008).

The research is clear in recommending that a multi-component intervention should be used in schools. Ideally, any intervention development should take a whole school approach and include components targeting FMS through PE lessons, active breaks, active classrooms, family engagement and the community setting (Acker et al., 2011). While these may be the most recommended strategies through previous research, it may be unfeasible to implement all components in a real world setting when creating an intervention programme. It is therefore imperative to examine previous school based interventions targeting FMS in order to ascertain the most effective strategies.

Interventions targeting FMS in Children

As briefly mentioned earlier, the SPARK programme (n = 745, mean age 9.25 years) aims to increase FMS and PA through a PE programme with age appropriate activities (Sallis et al., 1997). While the programme dates as far back as 1989, it was among the first that included activities to improve fitness and activities to increase skills (McKenzie et al., 2009). The resources provided divide the lessons into two main components, one focusing on developing HRF, and the other aspired to develop motor or sport skills. The 30 minute lessons were guided by the PE curriculum and various studies reported success on several outcomes, such as increased PA during PE (n = 955, mean age = 9.56, 53% male, $p < 0.001$) (Sallis et al., 1997), increased physical fitness levels (n = 955, mean age = 9.56, 53% male, $p = 0.03$, $d = 0.318$) (Sallis et al., 1997), and increased FMS development (n = 709, mean age = 9.5, 50.4% male, $p = 0.005$, $d = 0.29$) (McKenzie et al., 1998). The researchers evaluated the programme after it was delivered through two separate strands: one delivered by a PE specialist, one delivered by a trained teacher, while another group acted as a control and received no intervention. Sallis et al. (1997) reported superior outcomes through the PE specialist's compared to their trained teacher counterparts, although the trained teachers did achieve significantly greater results than the control group teachers. McKenzie et al. (2009) reported increases in teaching quality among the trained teachers subsequent to the intervention training. While a PE specialist is the preferred option to increase children's PA and skills, it is worth noting that teacher training can also be effective in positively increasing children's PA (McKenzie et al., 2009). In Ireland, generalist teachers are responsible for delivering PE in primary schools, with specialist PE teachers only employed at the post-primary school stage. Research has shown that primary school teachers feel poorly prepared to teach PE in an effective manner (Fletcher & Mandingo, 2012). Identifying strategies to improve generalist teacher's competence and confidence in delivering PE should be a key consideration in efforts to improve the quality of PE in the primary school setting (Fletcher & Mandingo, 2012).

The 'Move it Groove it' intervention in Australia was an FMS based intervention delivered through PE lessons in primary school children (n = 1045, age range 7 – 10 years) (van Beurden et al., 2003). The multi component approach included teachers, principals and parents, and a website containing intervention resources. There was also an educational element, with four teacher training workshops being provided, alongside equipment grants. The intervention group showed substantial improvements, measured through the Get Skilled: Get Active tool, with FMS increasing 18.5% over the course of a year (van Beurden et al., 2003). The intervention also resulted in a non-significant 4.5% rise in MVPA, and a significant increase of 3% in vigorous PA (van Beurden et al., 2003). While these findings only result in less than a minute increase in MVPA per session, it does show that the 'Move it Groove it' intervention can increase FMS proficiency and to a lesser extent PA in children.

Martin and colleagues (2009) implemented an FMS intervention over a six week period consisting of approximate half hour sessions with each class receiving 30 sessions (n = 64, mean age 5.55 years). The researchers employed two strands of the intervention, one delivered by a teacher using a mastery motivational approach, and the other delivered by a teacher using a low autonomy approach (Martin, Rudisill, & Hastie, 2009). The research on motivation suggest that children's learning and performance can be improved through the utilisation of a mastery motivational climate (Duda, 1995). A mastery climate is one in which individuals value the learning process, have a desire for skill development, and believe that effort leads to success or improvement (Nicholls, 1989). The more traditional low autonomy method in contrast is teacher centred, uses direct instruction to improve FMS, and is visibly a very 'orderly' class (Silverman, 1991; Sweeting & Rink, 1999). Using the TGMD-2 as the measurement tool, participants in the mastery class achieved significant improvements in FMS from pre to post intervention ($p = 0.001$), while the low autonomy version failed to elicit any significant change (Martin et al., 2009). These findings suggest that merely implementing an FMS intervention is not enough, but the climate in which it is delivered is important to its success.

Many researchers across the world have used an iteration of the TGMD as a means to evaluate the effectiveness of their intervention programme on FMS proficiency. In Iran, an eight week intervention consisting of three 45 minutes sessions aimed at increasing FMS in young girls (n = 40, mean age 8.9 years) showed significant increases in both locomotor (mean increase = 6.15) and object control skills (mean increase = 7.75) and no significant change in the control group (Bakhtiari et al., 2011). The Supporting Children's Outcomes using Rewards, Exercise and Skills (SCORES) intervention was designed for low socio-economic status communities and was delivered through two 30 minute sessions per week over the course of a year in the USA (Cohen et al., 2015). Using the TGMD-2 as an evaluation tool, they found significant increases in overall FMS proficiency (n = 460, mean age 8.5 years, mean increase 10.6) pre to post testing (Cohen et al., 2015).

In New Zealand, ‘Project Energize’ is a teacher led FMS programme for school children, with 242 schools and nearly 53,000 children taking part since 2005 (Rush et al., 2016). The programme aims to improve health through positive eating behaviours and increased PA. One aspect of the programme is the emphasis placed on a well-trained and knowledgeable workforce. The person who delivers the programme is not a teacher and is classed as an external provider. The role, known as the ‘Energizer’, is defined as someone “*essential to the ability of the programme to penetrate schools and work with them*” and they must also be qualified and experienced in sport and FMS, amongst other things (Rush et al., 2016). Mitchell et al. (2013) reports that FMS significantly increased upon completion of the ’Project Energize’ intervention (n = 598, p < 0.001). ‘Project Spraoi’ is the Irish version of the ‘Project Energize’ initiative. Similar methods were employed as in New Zealand, with an ‘Energizer’ going into participating schools and implementing a multicomponent FMS intervention (Bolger et al., 2019). Using the TGMD-2 as a measure, Bolger and colleagues (2019) examined the effect of two interventions deployed through ‘Project Spraoi’ and found significant improvements in locomotor skill proficiency in the first (n = 181, approximate age 6 years, p<0.05), and the second found significant improvements in overall FMS proficiency (n = 195, approximate age 10 years, p < 0.001), including both the locomotor and object control subtests.

Table 2.3 Description of FMS intervention study characteristics.

STUDY	INTERVENTION PROVIDER	DURATION	SAMPLE TYPE	SAMPLE SIZE	MEAN AGE	FMS ASSESSMENT	SCORE TYPE	EFFECT SIZE	SIG (P)
BAKHTIARI ET AL., 2011	Researchers	8 weeks	Typically developing	40	8.9	TGMD-2	Raw	-	Y
						Locomotor		-	Y
						Object Control		-	Y
BOLGER ET AL., 2019	Specialised teacher	8 weeks	Typically developing	181	6	TGMD-2	Raw	-	N
						Locomotor		-	Y
						Object Control		-	N
	Specialised teacher		Typically developing	195	10	TGMD-2	Raw	-	Y
						Locomotor		-	Y
						Object Control		-	Y
COHEN ET AL., 2015	Trained teachers	School year	Low SES	460	8.5	TGMD-2	Raw	-	Y
						Locomotor		-	Y
						Object Control		-	Y
MARTIN ET AL., 2009	Researchers	6 weeks	At risk of DD	64	5.6	TGMD-2	Raw		Y
						Locomotor		0.54	Y
						Object Control		0.23	Y
	Researchers	6 weeks	At risk of DD	22	5.4	TGMD-2			Y
						Locomotor		0.01	Y
						Object Control		0.12	Y
MCKENZIE ET AL., 1997	Specialised PE teacher Control group	School year	Typically developing	709	7 to 10	Object control skills	Raw	0.29	Y
MITCHELL ET AL., 2013	Specialised teacher	School year	Typically developing	598	5 to 8	TGMD	% Proficiency	-	Y
						Locomotor Object Control			Y Y
VAN BEURDEN ET AL., 2003	Whole school approach	School year	Typically developing	1045	7 to 10	Get skilled: Get active	N/A	-	Y

It is clear that interventions targeting FMS proficiency in a school setting can be very effective in increasing motor competence (Lai et al., 2014; Logan et al., 2012a; Lubans et al., 2010). A review of interventions in young children showed significant improvements in FMS levels in most studies (Veldman, Jones, & Okely, 2016) which suggest that pre-school interventions are also effective. Several of the studies highlighted above contain similarities and this is important to consider when developing an intervention that seeks to target similar age groups. The most effective strategies to improve FMS proficiency appear to be those which include a multicomponent intervention in a school setting, particularly those which employ FMS specific lessons delivered by a trained teacher (Kriemler et al., 2011; Murillo Pardo et al., 2013; Timperio et al., 2004).

Intervention Design

According to the Medical Research Council, all interventions should be based on a relevant theoretical framework (Craig et al., 2008). Those which utilise a relevant theory when developing interventions to change behaviour are more successful than those who do not (Stull, Synder, & Demark-Wahnefried, 2007). Using a relevant theoretical framework allows for evaluation of the intervention, as well as examining ways in which the intervention can be improved (Michie & Abraham, 2004). The National Institute for Health and Care Excellence (NICE) (2014) reports behavioural changes come from an interaction between an individual's capability, opportunity and motivation to perform and carry out that behaviour. This is known as the Capability-Opportunity-Motivation Behaviour (COM-B) model and change is required in one or more of these components for any behavioural change to take place (Michie, van Stralen, & West, 2011). A recent review of behavioural change identified 19 frameworks. They were evaluated in relation to their coherence, comprehensiveness and links to models of behaviour (Michie et al., 2011). As no framework contained all three criteria, they were synthesised into the Behavioural Change Wheel (BCW) and contain the COM-B model at its core (Michie et al., 2014). The BCW guide to designing interventions aimed at changing behaviours outlines an evidence-based approach which provides designers with a full range of options to suit their needs (Michie et al., 2014).

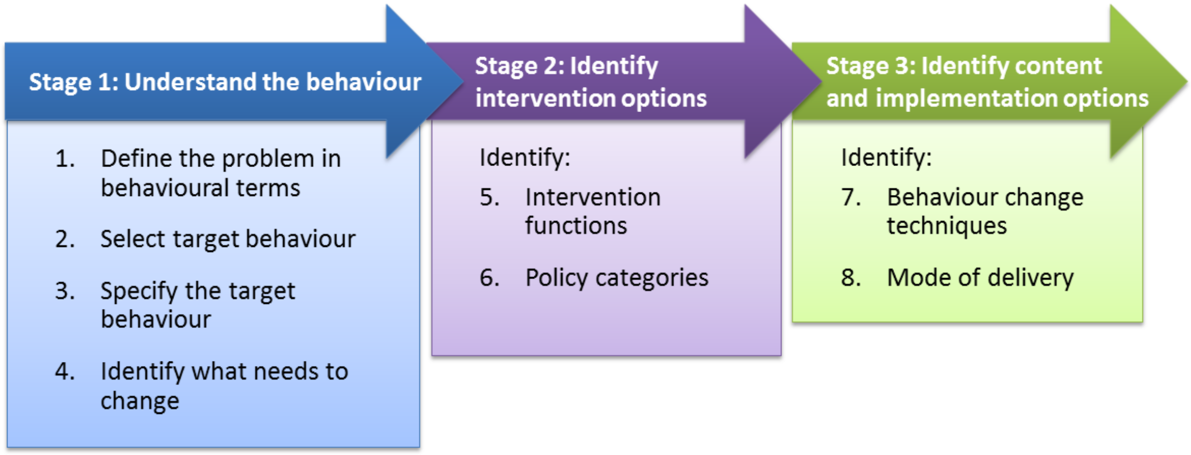

Figure 2.2. Behavioural Change Wheel Step by Step Method for Designing Behaviour Change Interventions (Michie et al., 2014)

The BCW provides a systematic process to designing and developing interventions and this helps diagnose why an intervention may or may not have failed to achieve its stated goals. This practical, simple and comprehensive tool has been used widely in both academic and policy fields, with a recent Irish study implementing the BCW through the design of an active classrooms intervention seeking to increase PA for example (Martin & Murtagh, 2017). It is aimed at health care providers, policy makers, and researchers seeking to change behaviour through interventions (Michie et al., 2014). The BCW "provides theoretically-based guidance and a structured method to facilitate the process of development and the opportunity to learn from the results" (Michie et al., 2014).

2.6 Current situation for Fundamental Movement Skills in Ireland

It seems clear from the evidence presented in this review that more emphasis must be put on FMS development in Irish primary schools. PE programmes concentrating on FMS have been shown to be very effective, particularly when taught by qualified professionals (Strong et al., 2005). It is logical therefore that FMS development should form a core element of any primary PE curriculum. While Ireland's primary PE curriculum does mention a focus on "motor development" (Department of Education and Skills, 1999, p.6), there is little structure and guidance for the practitioner, with just one hour per week recommended to be allocated to PE (Department of Education and Skills, 1999, p.6). Coupled with the fact that the primary school teachers in Ireland are non-specialised and are expected to cover 12 curriculum subjects (Department of Education and Skills, 1999), it is not surprising to see the poor FMS levels reported in Irish children (Bolger et al., 2018; Farmer et al., 2017; Kelly et al., 2018). As a first step, it seems clear that research at a national level is needed to give an accurate picture of Irish children's FMS proficiency levels across the lifespan of primary school.

While it is purported that FMS can be mastered as early as six years of age (Gallahue & Ozmun, 2006), it is widely expected that children should have mastered all FMS by the age of ten (Hardy et al., 2010). Proficiency levels vary across countries but FMS proficiency remain consistently low (Barnett et al., 2009; Kelly et al., 2018; Lubans et al., 2010; Mukherjee et al., 2017). Irish data similarly reports low levels of FMS mastery in several pockets around the country (Bolger et al., 2018; Farmer et al., 2017; Kelly et al., 2018). These studies have limitations however, as most research on FMS in Irish primary schools is limited due to the relatively small, local sample sizes (Bolger et al., 2018; Farmer et al., 2017; Kelly et al., 2018), mainly due to the fact that it is being carried out by individual researchers. Results produced therefore lack generalisability and cannot be taken as representative of the entire population A nationwide FMS assessment would provide baseline measures, and provide a means of evaluating change. Data collection of this scale presents several challenges, particularly in terms of logistics and personnel. Assembling and training a research team to collect a national sample would take considerable resources. Future research should seek to form collaborations with existing bodies, be they academic institutions, sports organisations, or other groups in order to ascertain the true FMS proficiency levels of Irish children. These partnerships could utilise existing infrastructures nationwide to facilitate the collection of data.

2.7 Summary

The concept of physical literacy is a complex and multi-faceted. PL is commonly defined as "*the motivation, confidence, physical competence, knowledge and understanding to be physically active for life*" (IPLA, 2015), and is purported to be a key driver of children's physical activity (PA). The health benefits of increased PA are well established (Ortega et al., 2008; Ruiz et al., 2006) and, with declining levels of PA reported worldwide (Beals et al., 2016; Bryant et al., 2014; Hills, Anderson, & Byrne, 2011; Woods et al., 2010), it is clear that research exploring PL in children should be undertaken. While researchers have attempted to capture PL in children, a consensus on the most effective way to do so has not been reached (Edwards et al., 2018). In order to better understand the complexities of PL, its components should be examined in greater detail, and this work will focus on the physical competence element. The physical competence component consists of an individual's health related fitness properties (Tremblay et al., 2018) and also the individual's basic motor skill proficiency, commonly referred to as fundamental movement skills (FMS) (Logan et al., 2018).

FMS are the basic building blocks on which more sports specific skills are built (Logan et al., 2018). Acquiring these skills allow for participation in sport and various forms of physical activity (McKenzie & Lounsbery, 2008; Metcalfe & Clark, 2002). Research has shown that those with a greater FMS proficiency as children go on to be more physically active as adolescents (Barnett et al., 2009; Hardy et al., 2013; Jaakkola et al., 2016; Stodden et al., 2008). These basic skills must be taught and developed (Clark, 2007; Haywood & Getchell, 2019; Cools et al., 2009), and the school setting has been identified as an important environment in which to do this (McKenzie & Lounsbery, 2009). Primary schools in particular are important with PE identified as a key contributor towards an active lifestyle (McKenzie & Lounsbery, 2014).

The evidence suggests that an intervention among children of primary school age is warranted to ensure mastery of the FMS thus providing children with a solid foundation upon which to build sport specific skills (Lubans et al., 2010; Clark, 2007). There are also widely reported gender differences in FMS performance among children, with males consistently outperforming their female counterparts in object control skills (Bardid et al., 2016; Barnett et al., 2010; Kelly et al., 2018; Okely & Booth, 2004; van Beurden et al., 2002). This is another reason why FMS assessment in primary schools should be a priority for researchers going forward, as planning and evaluating an effective intervention will prove difficult without first having representative baseline data.

There are many tools used to measure FMS utilised in research. Through this review, the TGMD has been shown to be a widely used, robust and reliable tool for assessing FMS (Belton et al., 2014; Logan et al., 2017; O'Brien et al., 2015; O'Brien et al., 2013; Khodaverdi et al., 2015; Barnett et al., 2008). It is however, missing a stability component. FMS are comprised of locomotor, object control, and stability skills (Gallahue & Ozmun, 2006), and as such, any future FMS research should seek to include some form of stability assessment in its test battery (Rudd et al., 2015).

A constraint hampering researchers from undertaking studies with large sample sizes is the pen and paper method traditionally utilised during the data collection of FMS research. Recording data in this manner in fact increases the workload for the researcher, who upon completion of assessment, must then manually input to a database. As well as the additional time involved, the method also produces opportunity for error during the data entry process. Some have looked at technological solutions to collect data (van Rossum & Morely, 2018), and while these still have some issues with scalability and privacy issues, it seems only a matter of time before the pen and paper method is replaced. Future research should explore innovative ways in which to collect data, particularly those in which technology is employed that can dramatically reduce researchers workload, and limit the risk of user entry error.

The literature provides substantial evidence highlighting the benefits of FMS, particularly the benefits FMS has towards PA (Barnett et al., 2009; Jaakkola & Washington, 2013; Lubans et al., 2010). FMS are positively associated with both overall PA (Fisher et al., 2005) and MVPA in children (Wrotniak et al., 2006). With the positive health outcomes associated with PA and MVPA, these relationships cannot be ignored and give further evidence that a focus on FMS in primary schools should be a priority. To better understand FMS proficiency levels, and to target effective improvements in FMS, it is important to also understand the various relationships FMS has with correlates such as HRF components (Cattuzzo et al., 2016; Lubans et al., 2010). For instance, FMS has a strong association with CVE, with several studies showing those with high levels of FMS proficiency also have high levels of CVE, and vice versa (Cattuzzo et al., 2016; Haga, 2009; Lubans et al., 2010) The benefits of CVE are well established, with high levels being positively associated with reduced risk of cardiovascular disease, adiposity, and mental health (Ortega et al., 2008). While several studies use CVE as a proxy for HRF when exploring the relationship with FMS, it is important to note that FMS has established positive relationships with all components of HRF bar flexibility, and these should not be ignored. Stodden and colleagues (2008) combined HRF components into a composite score and reported findings that showed the relationship between HRF and FMS is dynamic, and changes across the course of a child's life. The same study proposes that this relationship could be a key driver in a positive trajectory towards PA participation (Stodden et al., 2008). It did, however, employ a narrow range of FMS assessments, and future studies should utilise a broader array of FMS assessments, as well as examining the relationship FMS has with each of the HRF components.

It is evident from previous research that FMS proficiency levels are consistently low globally (Barnett et al., 2009; Kelly et al., 2018; Lubans et al., 2010; Mukherjee et al., 2017). It is clear that there is a need not just to assess and monitor FMS development across childhood, but also to intervene. The school setting has been shown to be particularly successful for interventions aimed at developing FMS (Lai et al., 2014; Logan et al., 2012; Lubans et al., 2010; Veldman et al., 2016) Any intervention should be multi-component in order to elicit lasting change (Kriemler et al., 2011; Murillo Pardo et al., 2013; Salmon et al., 2007; Timperio et al., 2004). As previously discussed, positive results can be achieved through the inclusion of components such as targeted PE (Salmon et al., 2007), active classrooms (Martin & Murtagh, 2015), family engagement (O'Brien et al., 2013) and community involvement (Acker et al., 2011). It is also crucial that any intervention should be based on a relevant and robust theoretical framework (Craig et al., 2008; Stull et al., 2007). There are many frameworks utilised in research in which positive results have been achieved. The behavioural change wheel (BCW) has been shown to be successful in the design of effective interventions that target behavioural change (Michie et al., 2014). Through its systematic process, it has been particularly helpful in diagnosing the reasons why an intervention was successful, or unsuccessful, in achieving its goals (Michie et al., 2014). Future interventions should adhere to the framework outlined by the BCW in order to give the intervention its highest chance of success, and to ensure that it can be properly evaluated afterwards. Knowing the low FMS proficiency levels that exist, and the importance of FMS towards PA participation, the evidence for an FMS intervention in primary schools has been well established.

Substantial evidence has been presented throughout this review advocating the importance of FMS, particularly its relationship with PA participation (Barnett et al., 2009; Jaakkola & Washington, 2013; Lubans et al., 2010) and the associated health benefits (Cattuzzo et al., 2016; Lubans et al., 2010). While multiple studies worldwide assess FMS through small convenient samples (Bolger et al., 2018; Farmer et al., 2017; Kelly et al., 2018), there are few that seek to measure large scale sample sizes. A representative sample would provide robust baseline data so that effective interventions could be designed and progress could be measured. Future research should look to carry out large cross-sectional data collection in order to establish these baselines, not just in FMS but in HRF and other related variables also. The research suggests that FMS and HRF have a dynamic relationship (Stodden et al., 2008), yet few have examined all the HRF components against a broad range of FMS across childhood. Only when such research has been undertaken will it enable the design and development of effective, evidence based and culturally specific interventions that are underpinned by relevant frameworks.

Chapter 3: Moving Well-Being Well: Investigating the maturation of fundamental movement skill proficiency across sex in Irish children aged five to twelve

Manuscript submitted as: Moving Well-Being Well: Investigating the maturation of fundamental movement skill proficiency across sex in Irish children aged five to twelve.

Journal of Sports Science - accepted 16th July 2019, published online 5th August 2019.

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3.1 Abstract

Fundamental movement skills (FMS) are the basic building blocks of more advanced, complex movements required to participate in physical activity. This study examined FMS proficiency across the full range of Irish primary school children (n = 2098, 47% girls, age range 5-12 years). Participants were assessed using the Test of Gross Motor Development, 3rd edition (TGMD-3), Victorian Fundamental Movement skills manual, and the balance subtest from the Bruininks-Oseretsky Test of Motor Proficiency 2 (BOT-2). Independent sample t-tests and a one way between groups ANOVA with planned comparisons were used analyse sex and age differences. Mastery or near mastery of skills ranged from 16% for overhand throw, to 75.3% for run. Girls scored significantly higher than boys in the locomotor and balance subtests with the boys outperforming the girls in object control skills. Improvements in ability can be seen over time ($F(8,1968) = 70.18$, $p < 0.001$), with significant increases in FMS proficiency seen up to the age of ten, after which proficiency begins to decline. The findings demonstrate the low levels of FMS proficiency amongst Irish primary school children, the differences between sex that exist, and highlights the need for more programmes that focus on developing these FMS at an early age.

Keywords: Fundamental movement skills; FMS; TGMD-3; motor competence; motor development; physical activity.

3.2 Introduction

The benefits of participation in regular physical activity (PA) are well documented (Warburton et al., 2006). A report by the American Physical Activity Guidelines Advisory Committee (2018) states physically active children have reduced risks of excessive increases in body weight, cardiovascular disease, osteoporosis, and type 2 diabetes, as well psychological and emotional benefits such as increased mental health, higher self-esteem and better emotional self-efficacy (Eime, Young, Harvey, Charity, & Payne, 2013). The current guidelines state that children and adolescents should engage in at least one hour of moderate to vigorous physical activity (MVPA) each day, yet research from around the world suggests that children and adolescents typically fall well below this target (Cavalheri, Straker, Gucciardi, Gardiner, & Hill, 2016; Colley et al., 2017; Katzmarzyk & Staiano, 2017). In Ireland alone, the Children's Sport Participation and Physical Activity (CSPPA) study found just 10% of Irish adolescents engage in the recommended one hour per day of moderate to vigorous activity (Woods et al., 2010). It is therefore important to identify factors that influence PA participation to increase physical activity levels in children and youths; one of them being their motor skill proficiency level.

Fundamental movement skills (FMS) are purported to have a significant impact in PA participation, with increased proficiency associated with increased PA in adolescents (Robinson et al., 2015). FMS are the building blocks of more advanced, complex movements required to participate in to participate in games, sports or other context specific physical activity (Logan et al., 2018). The three domains of FMS are: locomotor skills (running and jumping, etc.), object control skills (throwing and kicking, etc.), and stability skills (i.e. balance) (Gallahue & Ozmun, 2006). Once refined and combined, these FMS support the acquisition of sports specific complex movement skills (Metcalfe & Clark, 2002). A lack of proficiency would in turn have consequences in terms of reduced levels of PA participation (Jaakkola et al., 2016). The literature supports this evidence: FMS proficiency has shown positive associations with increased physical activity in both children (Barnett et al., 2009; Cliff et al., 2009; Robinson et al., 2015) and adolescents (Barnett et al., 2009; Lubans et al., 2010; Okely et al., 2001), with Stodden (2012) maintaining that early mastery of FMS can lead to a more active lifestyle over a lifetime.

Research indicates that early childhood is a critical period for FMS development (Barela, 2013; Hardy et al., 2013). Clark (2007) illustrates that FMS must be developed through practice. In addition, girls and boys do not typically progress to mastery level at the same rate (Cliff et al., 2009). Research suggests differences in FMS proficiency between sex in children of the same age, with girls displaying higher proficiency in locomotor and stability skills, and boys achieving higher scores in object control skills (Barnett et al., 2009; Erwin & Castelli, 2008; Goodway et al., 2013; Hardy et al., 2010). Gallahue and Ozmun (2006) report that children have the potential to master most of the FMS by the age of six, in contrast, Australian researchers suggest mastery can be achieved between nine and ten years of age (Hardy et al., 2010). It is therefore alarming to see a worldwide trend, with Australia (van Beurden et al., 2002), Singapore (Mukherjee et al., 2017) and Canada (LeGear et al., 2012), among countries failing to exhibit age appropriate FMS proficiency. O'Brien et al. (2016) measured FMS in Irish adolescents and found that only 11% could adequately perform the required movement patterns. This is concerning considering that these adolescents should have completed eight years of primary school physical education, in which these basic movement skills are targeted throughout the curriculum (Irish Primary PE Curriculum, Department of Education and Skills, 1999).

The adolescent motor skill proficiency levels are well documented (Belton et al., 2014; O'Brien et al., 2016), but we still miss an overall picture of the proficiency level, and the rate of development, during the eight years of primary school. This study aims to, 1) Report nationwide FMS proficiency levels, 2) Explore the effect of maturation, and 3) Examine potential disparities between the sexes in FMS, across the age span of Irish primary school children.

3.3 Methodology

Participants

Cross-sectional data were collected as part of a national physical literacy study 'Moving Well-Being Well'. Over 50 schools were approached with 44 agreeing to take part (88% participation rate). Participants (n = 2098, 47% girls, ranging from 5-12 years of age, mean age 9.2 ±2.04) were then recruited from these 44 schools across twelve counties (56% rural, 44% urban), encompassing all four provinces in Ireland and Northern Ireland. Irish primary schools in areas classed as 'socioeconomically disadvantaged' qualify for the Delivering Equality of Opportunity in Schools (DEIS) programme, and comprise 19.7% of primary schools in Ireland (Junior et al., 2005). This study's sample includes 18.8% DEIS schools. Data were collected March through June 2017 across the full range of the primary school cycle, typically developing junior infants to sixth class. The subjects were classified per age and sex for data analysis.

Ethical approval was obtained from the institutional Research Ethics Committee (DCU/REC/2017/029). The principals of each of the participating schools initially consented to participation, while parental consent and participant assent were also obtained. An age appropriate child assent form was supplied to participants in the younger classes (junior infants to 2nd class, 5- 8 years of age). Participants were assigned a unique numerical code to ensure their anonymity was maintained, with age and sex collected through the consent forms and questionnaires administered in the classroom.

Measures

FMS proficiency was measured using the Test of Gross Motor Development-3rd Edition (TGMD-3). The TGMD-3 is comprised of locomotor (run, skip, gallop, slide, hop, and horizontal jump) and object-control (catch, overhand throw, underhand roll, kick, two handed strike, one handed strike, and stationary dribble) skill subtests (Ulrich, 2013). An additional locomotor skill test was included, the vertical jump, from the Victorian Fundamental Motor Skills manual (Department of Education Victoria, 1996, *Fundamental Motor Skills: A Manual for Classroom Teachers*, Melbourne: Education Department of Victoria). Both have been used in previous research and have a high degree of validity and reliability (Cools et al., 2009; *Fundamental Motor Skills: A Manual for Classroom Teachers*, 1996). The TGMD-3 and the vertical jump test assess the performance of skill components, rather than the outcome or product of performance, and again have established validity (Temple & Foley, 2017) and reliability (α = 0.81) in this age cohort (Cools et al., 2009; Yee et al., 2010).

While the TGMD is a common assessment tool used in many studies worldwide, some would criticise the lack of a stability component (Rudd et al., 2015). To this end, a subtest of the Bruininks-Oseretsky Test of Motor Proficiency 2 (BOT-2) Short Form was utilised to assess the participants' balance. The BOT-2 Short Form is a motor competence battery originally designed to identify individuals with mild to severe motor problems (Fransen et al., 2014). It has been widely used in previous research (Cools et al., 2009), and has proven validity (Fransen, D'Hondt, Bourgois, Vaeyens, & Philippaerts, 2014) and reliability (α = 0.92) (Crosetto et al., 2009; Fransen et al., 2014). The balance assessment consists of two tasks, walking forward along a straight line, and standing on one leg on a balance beam with eyes open. In contrast to the TGMD-3, these tests are based on the outcome of the performance, and participants are awarded points on a scale from zero to four for each task (Deitz, Kartin, & Kopp, 2009). While the preference would have been to use a process -based stability assessment for consistency purposes, the authors deemed that there were no existing and valid process-based stability assessment suitable for use in this study.

Data Collection

All research team members were required to undergo formal training in order to ensure thorough understanding of the skill assessment process as well as consistency in assessing the test subjects. In order to ensure consistent and high quality data, the team were required to meet a 95% inter-observer agreement on a pre-coded data set. This data set was pre-coded by the lead researcher and the research team members were blind to the conditions of coding. Prior to assessment, a visual demonstration of the skill was performed by a trained member of the research team, consistent with the protocol defined by Ulrich (2013), and widely used throughout the literature (Cools et al., 2009; Ulrich, 2013). There were no verbal feedback or cues and participants were unaware of the specific components being measured. Participants were each asked to perform every skill twice, after first completing a practice trial to familiarise themselves with the skill. A trained member of the research team observed each trial and assessed each skill component. The number of skill criteria varies from three to six across the various skills. A score of one was noted if the participant fulfilled the necessary criteria, and a zero indicates that they failed to meet these criteria. The scores from both trials were totalled and this indicates the participants raw score per skill. Upon completion of all skill assessments, the locomotor and object control skills were totalled to give raw subtest scores, before being combined to give an overall raw FMS score.

The first balance subtest, walking forward on a straight line, is graded based on the amount of steps a participant takes while adhering to strict criteria (Bruininks, 2005). Points were awarded to the participant in line with the number of steps taken, e.g. six continuous steps equal four points. Standing on one leg on the balance beam was scored based on the time a child could maintain their balance while adhering to the prescribed criteria (Bruininks, 2005). Again, points were awarded based on the time a participant kept their balance, e.g. over ten seconds equals four points. If a participant scored maximum points in the first trial, there was no need to complete a second trial.

Traditionally, the process orientated FMS assessments are measured by using the pen and paper method (Ulrich, 2013; Yun & Ulrich, 2002). A similar pen and paper method has been used in the past for the balance test (Bruininks, 2005). All scores must then be input into a database before any statistical analyses can be undertaken. These methods are time consuming as well as doubling the opportunity for human error to occur during data entry. To counteract this, a unique iPad application was developed to collect the data. The equivalent of the paper version was created in the iPad application. This app allowed the research team to assess the participants through their unique numerical code using electronic tablets. Throughout the process based assessments, the assessor clicked a skill component box on the touchscreen if the skill criteria was fulfilled, and left the box blank if not. All checked boxes were recorded as a one and unchecked boxes as a zero. The balance test was also recorded on the app, with a checkbox system for walking forward on a straight line, and an inbuilt timer for the balance beam assessment. The protocols for each assessment were followed at all times (Bruininks, 2005; Ulrich, 2013). When connected to a secure network, the tablet uploaded the complete data set to a secure server based on the university campus. The app can be used by multiple users at a time and allows for a secure cloud based upload of pseudo-anonymised data. This database can be downloaded then provides secure access for analyses, without the need for manual data entry. The system has been approved by the University's

Ethics committee and is also compliant with the new European general data protection regulations (GDPR).

Data Analysis

All data were analysed using SPSS version 24. Descriptive statistics and frequency tables were produced to determine the percentage of participants who had achieved mastery or near mastery in each skill. 'Mastery' of the process oriented locomotor and object control skills is the correct performance of all the skill components associated with each skill over both the trials. 'Near Mastery' is when an individual performs all but one of the components correctly over both trials (van Beurden et al., 2002). Any participant who did not fulfil the criteria to achieve mastery or near mastery status was classified as poor (Booth et al., 1999). Mastery for the product based balance assessment is classified as scoring the maximum score of four in each of the assessments to give a total of eight points (Bruininks, 2005). Using the above techniques, the raw scores for each skill were categorised into an additional variable and coded as mastery/near mastery (MNM), or poor (Okely & Booth, 2004). Frequencies were calculated to report a MNM percentage for each individual skill.

A commonly held hypothesis is that FMS proficiency improves through maturation (Goodway et al., 2013). In order to examine this hypothesis, a one-way between-groups ANOVA with planned comparisons was used to explore the impact of age on overall FMS, locomotor, object control, and balance skills. Statistical significance was set at $p<0.05$. Participants were grouped by age and comparisons were planned to compare each age group to the next in chronological order. Effect size is reported using eta squared, which classifies 0.01 as a small effect, 0.06 as a medium effect and 0.14 as a large effect (Cohen, 1988).

Individual skills were categorised by age and independent sample t-tests were used to analyse differences between sex in the locomotor, object control and balance subtest scores, as well as the overall FMS totals. The vertical jump was added to the locomotor subset. The overall FMS score is made up of the raw scores of the locomotor, object control and balance subtests.

3.4 Results

Only participants who returned completed parental consent and assent forms (n = 2098, 47% girls) were eligible for inclusion in the study. The sample consisted of Irish primary school children, participants ranging in age from five to 12. The overall FMS score (Figure 1) was calculated only for those who had complete data for all three subsets (n = 1968 participants, 47.2% girls). Similarly, only participants who were assessed in all components of the locomotor (n = 1979, 46.9% girls), object control (n = 2024, 46.7% girls), and balance tests (n = 2038, 46.9% girls), were included in the subset samples. When examining MNM in individual skills (Figure 1), the skill that demonstrated the highest percentage of proficiency was run at 75.3% MNM, with the poorest performed skill being the overhand throw, which achieved just 16% MNM.

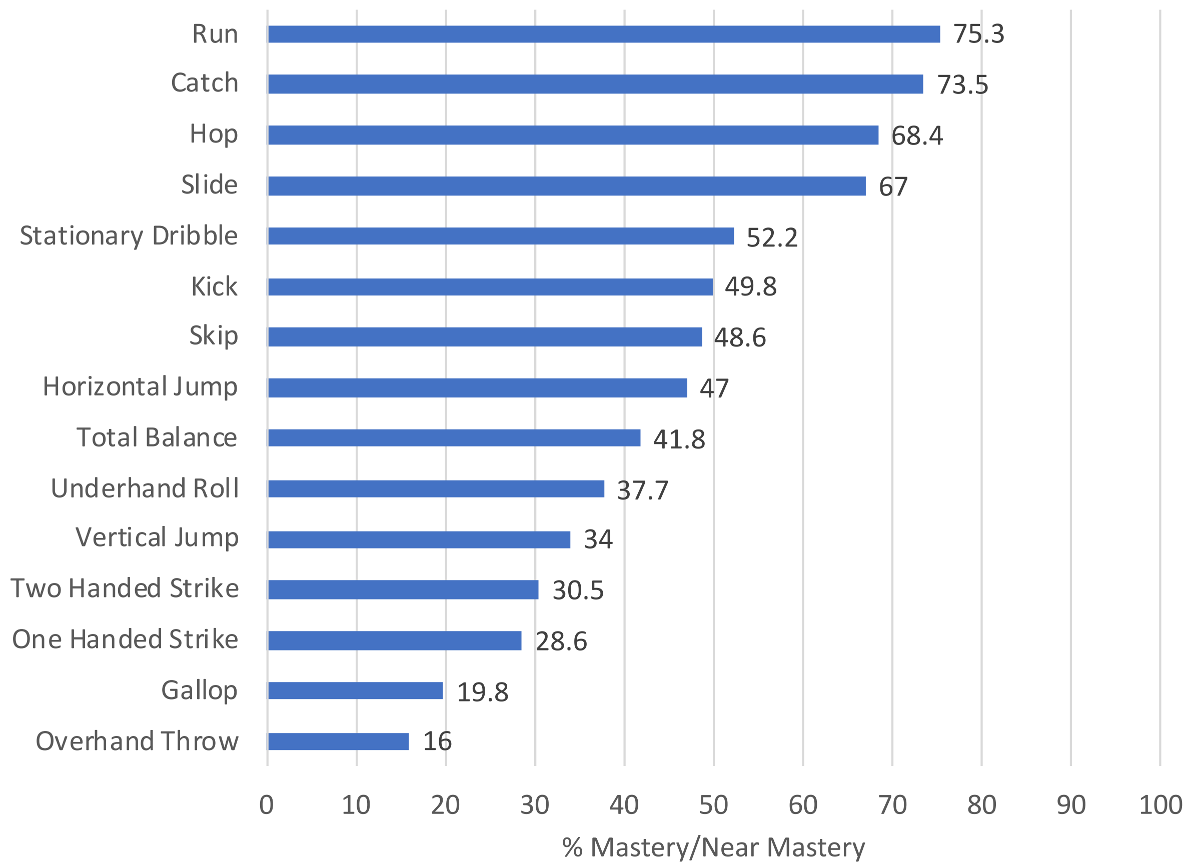

Figure 3.1. Percentage of Mastery/Near Mastery for locomotor and object control

A more comprehensive look at the MNM across the school age span can be seen in Table 1, which shows a breakdown of MNM by age category for each individual skill, as well as the overall FMS and the; locomotor, object control and balance subsets.

Table 3.1. Percentage of mastery/near mastery across the age-span of school going children

	AGE							
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	n=117	**n=250**	**n=318**	**n=302**	**n=360**	**n=277**	**n=270**	**n=175**
RUN	**73.5**	**69**	**77.5**	**78.3**	**73.5**	**81.3**	**77.2**	**67.8**
SKIP	**30.8**	**32.3**	**40.3**	**47.8**	**52.7**	**57.9**	**59.6**	**59.1**
GALLOP	**6.0**	**10.0**	**12.0**	**21.6**	**22.5**	**26.7**	**28.5**	**22.7**
SLIDE	**31.6**	**57.3**	**57.1**	**67.7**	**81.7**	**78.0**	**65.2**	**73.3**
HOP	**46.2**	**58.4**	**60.8**	**69.2**	**68.2**	**78.1**	**82.2**	**76.2**
HORIZONTAL JUMP	**29.1**	**31.4**	**44.4**	**41.2**	**50.1**	**53.8**	**52.1**	**65.7**
VERTICAL JUMP	**9.4**	**15.9**	**26.3**	**35.2**	**36.9**	**42.1**	**46.6**	**45.9**
CATCH	**41.9**	**54.0**	**62.9**	**76.9**	**81.1**	**85.0**	**83.8**	**85.5**
OVERHAND THROW	**5.1**	**4.8**	**13.0**	**14.6**	**12.4**	**21.6**	**26.9**	**26.7**
UNDERHAND ROLL	**12.1**	**23.4**	**28.2**	**35.5**	**37.0**	**46.3**	**53.9**	**55.8**
KICK	**29.1**	**30.9**	**37.3**	**46.8**	**49.6**	**61.9**	**67.9**	**69.8**
TWO HANDED STRIKE	**20.5**	**23.7**	**29.4**	**25.9**	**28.2**	**38.1**	**41.0**	**31.2**
ONE HANDED STRIKE	**8.5**	**13.3**	**16.2**	**21.7**	**27.6**	**41.3**	**48.7**	**45.7**
STATIONARY DRIBBLE	**8.5**	**27.6**	**35.6**	**51.2**	**68.7**	**68.1**	**63.5**	**68.8**
TOTAL BALANCE	**10.3**	**23.2**	**27.4**	**40.4**	**54.4**	**64.3**	**59.6**	**60.6**
TOTAL LOCOMOTOR	**29.0**	**35.0**	**40.7**	**46.1**	**49.3**	**53.5**	**52.8**	**52.8**
TOTAL OB CON	**18.0**	**25.4**	**31.8**	**38.9**	**43.5**	**51.8**	**55.1**	**54.8**
TOTAL FMS	**25.2**	**32.3**	**38.6**	**45.3**	**49.3**	**55.7**	**56.9**	**56.7**

A one-way between-groups ANOVA with planned comparisons was used to explore the impact of age on overall FMS, locomotor, object control, and balance skills (Figure 2). There was a statistically significant difference at the $p<0.05$ level in overall FMS scores, ($F(7,1950) = 103.72$, $p < 0.001$), with a large effect size calculated using eta squared of 0.27. Similarly, there was a statistically significant difference in the locomotor skill scores, ($F(7,1964) = 51.47$, $p < 0.001$), with a large effect size of 0.16. There was also a statistically significant difference in the object control skills, ($F(7,2011) = 101.15$, $p < 0.001$), with a large effect size of 0.26. Lastly, there was a statistically significant difference in the balance skill scores, ($F(7,2039) = 31.88$, $p < 0.001$), with a moderate effect size of 0.10.

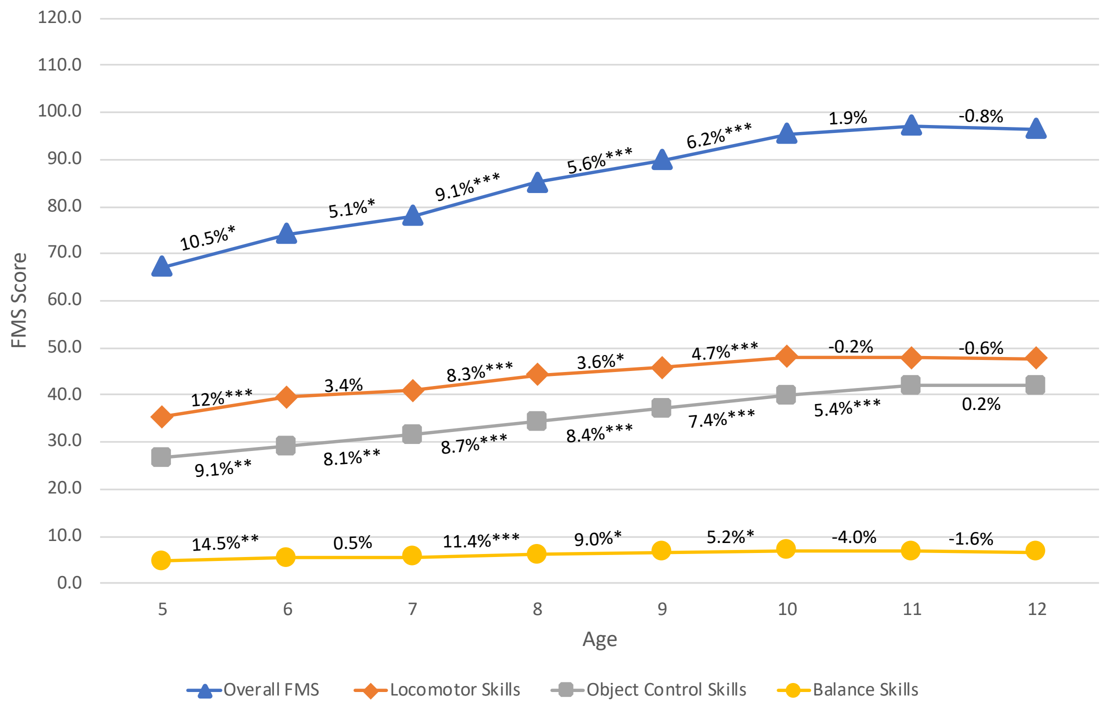

*Figure 3.2. Percentage change between age groups of raw scores for locomotor, object control, balance, and overall FMS scores. Significant differences between ages noted with an asterix, p<0.05 = *, p<0.01 = **, P<0.001 = ***.*

The planned comparisons compare each age group to the one above it, for example five years of age to six years of age. In overall FMS scores there is a significant difference between five and six years of age ($F(1,255.9) = 18.84$, $p < 0.001$). There are also significant differences between; six and seven years of age ($F(1,549.9) = 6.08$, $p = 0.014$), seven and eight years of age ($F(1,591.5) = 21.91$, $p < 0.001$), eight and nine years of age ($F(1,567.6) = 14.71$, $p < 0.001$), and nine and ten years of age ($F(1,535.4) = 24.09.77$, $p < 0.001$). These findings are reflected in the three subtests, with the exception of locomotor ($F(1,541.9) = 2.41$, $p = 0.121$) and balance ($F(1,552.4) = 0.02$, $p = 0.882$) reporting no significant change between the ages of six and seven. Object control was the only subtest to report any significant difference between 10 and 11 years of age ($F(1,519.9) = 2.61$, $p = 0.001$). There are no significant changes between 11 and 12 years of age in any of the above and results are detailed in Figure 2.

Independent sample t-tests were conducted to compare overall FMS scores for boys and girls across the Irish primary school years (Table 2). The same methods were used to compare the three subtest scores; locomotor skills (Table 3), object control skills (Table 4) and balance skills (Table 5), for boys and girls.

Table3. 2. Mean (±SD) of overall FMS scores across age and sex

	BOYS			**GIRLS**			**SIG**	**CI**	**EFFECT**	**DIFF**
AGE	**N**	**Mean**	**±SD**	**N**	**Mean**	**±SD**	**P**	**95%**	**Eta^2**	**%**
5	**63**	**65.3**	**14.7**	**52**	**69.5**	**12.0**	**0.099**	**-9.23,0.8**	**0.02**	**6.5%**
6	**137**	**75.2**	**16.1**	**105**	**73.0**	**15.3**	**0.283**	**-1.83, 6.22**	**0.00**	**3.0%**
7	**167**	**78.9**	**21.7**	**143**	**77.0**	**18.4**	**0.416**	**-2.63, 6.33**	**0.00**	**2.4%**
8	**149**	**84.6**	**18.8**	**145**	**85.6**	**14.5**	**0.618**	**-4.82, 2.87**	**0.00**	**1.2%**
9	**159**	**89.7**	**15.5**	**172**	**89.9**	**12.0**	**0.908**	**-3.19, 2.84**	**0.00**	**0.2%**
10	**129**	**96.5**	**15.4**	**116**	**94.2**	**10.4**	**0.163**	**-0.95, 5.61**	**0.01**	**2.5%**
11	**136**	**98.7**	**11.7**	**116**	**95.5**	**10.5**	**0.025***	**0.4, 5.95**	**0.02**	**3.3%**
12	**93**	**98.9**	**12.9**	**76**	**93.4**	**13.9**	**0.009****	**1.38, 9.52**	**0.04**	**5.8%**

Table 3.3. Mean (±SD) of locomotor skills scores across age and sex

	BOYS			**GIRLS**			**SIG**	**CI**	**ES**	**DIFF**
AGE	**N**	**Mean**	**±SD**	**N**	**Mean**	**±SD**	**P**	**95%**	**Eta^2**	**%**
5	**64**	**32.9**	**9.0**	**53**	**38.2**	**8.5**	**0.001*****	**-8.57, -2.1**	**0.08**	**16.2%**
6	**138**	**38.7**	**8.9**	**105**	**40.8**	**9.1**	**0.070**	**-4.4, 0.18**	**0.01**	**5.2%**
7	**167**	**39.8**	**11.5**	**144**	**42.2**	**10.6**	**0.051**	**-4.96, 0.01**	**0.01**	**6.2%**
8	**149**	**42.2**	**9.9**	**145**	**46.4**	**8.0**	**0.000*****	**-6.25, -2.12**	**0.05**	**9.0%**
9	**160**	**44.0**	**9.3**	**175**	**47.6**	**7.5**	**0.000*****	**-5.41, -1.79**	**0.04**	**8.2%**
10	**131**	**46.9**	**8.5**	**117**	**49.4**	**5.9**	**0.005****	**-4.39, -0.77**	**0.03**	**5.5%**
11	**137**	**47.8**	**6.9**	**118**	**48.3**	**7.2**	**0.577**	**-2.24, 1.25**	**0.00**	**1.0%**
12	**93**	**48.2**	**7.4**	**76**	**47.1**	**8.4**	**0.370**	**-1.3, 3.51**	**0.00**	**2.3%**

Table 3.4. Mean (±SD) of object control skills scores across age and sex

	BOYS			GIRLS			SIG	CI	ES	DIFF
AGE	N	Mean	±SD	N	Mean	±SD	P	95% CI	Eta^2	%
5	63	28.0	7.3	52	25.3	7.6	0.056	-0.07, 5.43	0.03	10.6%
6	137	31.4	9.0	107	26.3	7.9	0.000***	2.92, 7.26	0.08	19.3%
7	169	33.5	10.5	143	29.3	8.4	0.000***	2.07, 6.28	0.05	14.3%
8	151	36.1	10.7	146	32.4	8.2	0.001***	1.57, 5.92	0.04	11.6%
9	172	39.1	7.9	177	35.3	6.6	0.000***	2.26, 5.31	0.06	10.7%
10	141	42.3	7.7	128	37.3	6.8	0.000***	3.19, 6.7	0.10	13.2%
11	145	43.9	6.2	118	39.9	6.3	0.000***	2.48, 5.53	0.09	10.0%
12	94	44.1	5.9	76	39.3	6.6	0.000***	2.91, 6.69	0.13	12.2%

Table 3.5. Mean (±SD) of balance skills scores across age and sex

	BOYS			GIRLS			SIG	CI	ES	DIFF
AGE	N	Mean	±SD	N	Mean	±SD	P	95% CI	Eta^2	%
5	64	4.5	2.1	53	5.2	2.0	0.039*	-1.55, -0.04	0.04	17.8%
6	138	5.2	2.0	107	5.9	2.0	0.022*	-1.12, -0.09	0.02	11.5%
7	170	5.5	2.5	146	5.6	2.3	0.689	-0.64, 0.42	0.00	2.0%
8	153	5.7	2.2	147	6.7	1.9	0.000***	-1.49, -0.55	0.06	18.0%
9	173	6.4	2.1	183	7.0	1.7	0.002**	-1.01, -0.23	0.03	9.6%
10	144	7.0	1.6	130	7.1	1.7	0.634	-0.49, 0.3	0.00	1.4%
11	144	6.7	1.8	121	6.9	1.9	0.620	-0.57, 0.34	0.00	1.7%
12	97	6.5	2.0	77	6.9	2.0	0.192	-1.01, 0.2	0.01	6.2%

3.5 Discussion

The aim of this study was to conduct a national FMS assessment, with a key focus on the maturation of FMS proficiency across the age span of primary school, while investigating FMS disparities between sex in Irish children. The findings from this research shows the dearth of proficiency across all FMS components throughout primary school, with the children showing 60.6% of MNM in balance skills, while just over half achieve MNM in the locomotor (52.8%) and object control skills (54.8%).

Examining the MNM of individual skills (Figure 1), skills such as slide (67%), hop (68.4%), run (75.3%) and catch (73.5%) show relatively high levels of MNM. This is expected, as it has been established that these skills can be mastered by eight years of age (Gallahue & Ozmun, 2006). Armed with this knowledge, the low scores of the younger ages of five, six and even seven years of age can be expected as they have not reached their full maturation potential at this stage. As shown in Table 1 however, the older cohort also exhibit low scores and have not achieved MNM in any of the skills, with overhand throw (26.7%), one handed strike (45.7%), and two handed strike (31.2%) scoring particularly low among 12 year olds. Similar levels of MNM are seen among the nine year old participants and their Australian counterparts (Cliff et al., 2012), with slide (81.7%), underhand roll (37%), stationary dribble (68.7%), horizontal jump (50.1%), and catch (81.1%) all showing comparable results. It should be noted, the Australian children scored notably higher (Cliff et al., 2012) in skills such as two handed strike (28.2%), kick (49.6%), run (73.5%), and overhand throw (12.4%), with Irish children only surpassing them with the hop (68.2%).

Looking at recent Irish findings (Kelly et al., 2018), one handed strike (28.6%), horizontal jump (47%), and catch (73.5%) all show similar levels of MNM. In the same article, lower levels of MNM in several skills, such as run (42.7% vs 75.3%), hop (27.5% vs 68.4%), vertical jump (22.2% vs 34%) and kick (37.9% vs 49.8%). Conversely, the results presented here show lower proficiency in skills such as skip (69.4%), gallop (19.8%), stationary dribble (52.2%) and overhand throw (16%). The differences may be because of the inclusion of a wider age range (five to 12 years) and the large number of schools who participated in this study. Regardless of these differences, it is clear that Irish children are not mastering these basic skills (Bolger et al., 2018; Farmer et al., 2017; Kelly et al., 2018). Considering the Irish primary school PE curriculum places a heavy emphasis on movement skill development, it is particularly concerning that the level of MNM among the 12 year old participants is so low, specifically the object control skills. Higher skill proficiency has been reported in Irish adolescents (O'Brien et al., 2016) in the overhand throw (83% vs 26.7%), two handed strike (92%), stationary dribble (86% vs 68.8%), and kicking (98% vs 69.8%). Taking that some of the most popular extra-curricular sports in Ireland are Gaelic football, soccer, hurling, and basketball (CSSPA, 2010), the assumption could be made that this lack of basic skill proficiency could be having a detrimental impact on physical activity participation rates. O'Brien et al (2016) also report that just 23% of 12 to 13 year olds have MNM of the vertical jump, compared to the 45.9% MNM presented in this study's 12 year old participants. When one considers that the 11 year olds show greater proficiency (46.6%) than their 12 year old counter parts, it is concerning to see that the already low levels of proficiency in the vertical jump seem to decline with age. This finding is reflected in previous research, with adolescents showing similarly low levels of FMS proficiency (Hardy et al., 2010; Okely & Booth, 2004). This is alarming, as children who have not mastered the FMS are less likely to take part in PA due to a lack of basic movement skills (Barnett et al., 2009b; Lubans et al., 2010; Okely et al., 2001). With recent findings showing high levels of screen time and increased sedentary behaviour amongst Irish children (Harrison et al., 2013), and only 12% of Irelands youth achieving the recommended one hour of PA a day (Woods et al., 2010), these low levels of FMS proficiency should come as no surprise.

When comparing FMS proficiency across the primary school age-span (Figure 2), significant improvements in ability can be seen over time up to age ten. Increased proficiency as children get older is not surprising, as motor control typically develops as a child grows (Gallahue & Ozmun, 2006), however it does not occur naturally and mastery of these skills must be learned, practiced and reinforced (Hamilton, Goodway, & Haubenstricker, 1999; Robinson & Goodway, 2013). Considering this, one could expect to see significant developmental increases as the children progress through school, until mastery is achieved. As already shown (Table1), this is not the case, as there are low levels of mastery present across several skills, and only 56.7% of children achieve overall MNM by the age of 12. It is interesting to note that the improvements in proficiency plateau at ten years of age, not just in the overall FMS, but the locomotor and balance subtests too. Only object control continues to significantly increase from ten to 11 years of age, and overall FMS actually declines from 11 to 12 years of age, along with all three subtests. Understanding why these skills are not improving as they progress through school could be crucial to engaging more Irish children in long term physical activity. Future research should seek to understand why these skills are not being acquired. A limitation of this study is not taking the nested nature of the data into account, and future work should look to calculate the total variability in FMS scores to show a more nuanced view of school and participant level, rather than the overview presented here.

A difference between sexes in FMS proficiency has been suggested in children (Barnett et al., 2009; Erwin & Castelli, 2008; Goodway et al., 2013; Hardy et al., 2010), with previous Irish research showing boys scoring significantly higher in object control skills, and vice versa for girls in the locomotor skills (Bolger et al., 2018; Kelly et al., 2018). Looking at the overall FMS scores presented (Table 2) where significant differences between sex is only observed in 11 and 12 year olds, it would be easy to assume that there is no significant gap in Ireland. This assumption would be premature however, with girls scoring significantly higher in locomotor skills than boys at age; five, eight, nine and ten (Table 3). These findings should be taken with caution, however, as the effect sizes are small, with only a moderate effect size at age five. There are no significant differences between boys and girls for locomotor skills at age 11, but it is interesting to note that, while not significant, boys overtake girls in locomotor proficiency at the age of 12. Girls also scored higher than boys in the balance subtest at all ages (Table 4), scoring significantly higher at age; five, six, eight, and nine. Again, the effect sizes are small, with only age eight showing a moderate effect size.

Boys score significantly higher in object control skills (Table 5), with the exception of the five year old group, and corroborate Bolger et al. (2018) findings of Irish boys performing better in object control skills. While the boys significantly outscored the girls across most ages, it is interesting to note that the effect size increases in the older age groups, maintaining a moderate effect size across the ages of 10 to 12. This may represent a key turning point in girls object control development, as O'Brien et al. (2016) also shows female adolescents to have significantly less mastery of the object control skills. The CSPPA (2010) report shows 24% of Irish girls take part in dance compared to 4% of boys. This may explain why they develop their locomotor and balance skills faster. In contrast, the same report demonstrates that boys have a higher rate of extra-curricular sport participation in Ireland, predominantly made up of Gaelic games, soccer and rugby, all of which involve object control skills (CSPPA, 2010). A greater proficiency in object control skills has been suggested as a predictor of physical activity

(Barnett et al., 2009). Given that the most popular sports in Ireland revolve around object control skills (CSPPA, 2010), it seems prudent to place an emphasis on these skills in primary school aged children, particularly with girls. An increased proficiency in these skills at a young age could see the perceived competence of the child increase, which can give them confidence to take part in sport in later life, thus creating a positive spiral of engagement from an early age (Stodden et al., 2008).

Regarding the positive association between childhood FMS proficiency and PA levels in later life (Stodden et al., 2008), this study could have important implications for the future health of children. The health benefits associated with PA are substantial (Dobbins, Husson, & Decorby, 2013), and several studies have shown an inverse relationship between FMS competency and weight status (Lubans et al., 2010). Given the current obesity crisis (World Health Organisation, 2015, *Global trends in overweight an obesity)* and what we know about the benefits of PA (Warburton, Nicol, & Breddin, 2006), establishing FMS from an early developmental age should not be ignored. Interventions focusing on FMS development have been proven to be effective on numerous occasions (Hume et al., 2008; Okely & Booth, 2004; van Beurden et al., 2003), but despite this, there is a dearth of research in FMS proficiency in Irish primary school children. The lack of skills mastery shown here, and in other studies, can further emphasise the need to prioritise FMS development in children. It seems obvious that without these fundamental skills, attaining a high level of proficiency in any sport becomes significantly more challenging (Stodden et al., 2012; Stodden et al., 2008). In addition, the prevalence of withdrawal from physical activity participation is at its highest among teenagers (De Meester et al., 2009). Given the emerging evidence suggesting that developing FMS in children leads to less drop-outs in teenage years (Jaakkola & Washington, 2013), it seems paramount that FMS development be placed at the heart of any programme when planning physical education or sports specific training for young children.

Conclusion

The results of this study highlight the low levels of FMS mastery, outlines the plateau in maturation of motor skill development in the Irish primary school cycle, and further supports the hypotheses of the proficiency disparity in FMS that exists among boys and girls. It is expected that the results presented here will help to establish FMS norms of primary school children, both in Ireland and further afield. Future research should seek to explore Irish children's physical activity levels, along with health-related fitness measures, and examine the relationship between FMS and the afore mentioned components to expand on the hypotheses outlined in this paper in an Irish context, and further understand what motivates children to participate in physical activity.

Link from Chapter 3 to Chapter 4

Chapter 3 addressed a gap in the literature, particularly in an Irish context, in assessing the FMS proficiency of a large cross-sectional sample of primary school children. There have been other Irish studies examining FMS (Bolger et al., 2018; Farmer et al., 2017; Kelly et al., 2018), however these all acknowledge the limitation of small localised sample sizes. While large cross-sectional FMS research has been carried out in other countries, to best of the authors knowledge there is none have considered the entire spectrum of primary school. The results shown in chapter 3 allows the researchers to give an accurate depiction of the current status of Irish primary school children's FMS proficiency. The low levels of FMS mastery, gender discrepancies, along with the skills plateauing at age ten, give cause for concern given the purported links between FMS proficiency and future PA participation. The relationship between FMS and PA have been discussed extensively in this thesis. There are, however, some who maintain that this relationship is part of a wider construct, which includes perceived movement competence and health related fitness (HRF). It is suggested that the manner in which these components interact can result in either a negative or a positive trajectory towards health (Stodden et al., 2008). Others have reported findings showing indirect pathways from motor competence to PA engagement through HRF (Jaakkola et al., 2019). Any relationships with FMS that relate to PA, such as HRF, require further investigation.

Chapter 4 examines the relationship between FMS and HRF across the primary school cohort. The relationship between FMS and HRF is widely researched and the substantial evidence points to a positive relationship between the two (Cattuzzo et al., 2016a). Many of these studies however, use just a component of HRF, most commonly cardiovascular endurance, as proxy for HRF when investigating the relationship with FMS (Cattuzzo et al., 2016a). Stodden and colleagues (2014) used a composite HRF score, comprised of several HRF components, to examine the links with FMS, and report that the relationship between the two is dynamic. Unlike previous research, chapter 4 aims to examine the relationship between the full FMS range against each of the HRF components across the entire primary school cohort. This will allow the researchers to ascertain whether in fact the relationship between HRF and FMS is dynamic, as proposed by Stodden et al. (2014).

Chapter 4: Evolving dynamics between fundamental movement skills and health related fitness components in children

Manuscript submitted as: Evolving dynamics between fundamental movement skills and health related fitness components in children.

European Journal of Sports Science - submitted June 2019, under review.

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4.1 Abstract

This study examined the relationship between fundamental movement skills (FMS) and health related fitness (HRF) components in children. A cross section of Irish primary school children across all age groups participated in this study (n = 2098, 47% girls, age 5-12 years of age, mean age 9.2 ±2.04). FMS were measured using the Test of Gross Motor Development (TGMD-3), along with two additional assessments of vertical jump and balance. All HRF components were also assessed: body composition through BMI and waist circumference, muscular strength (MS) using a hand dynamometer, muscular endurance (ME) through the plank test, flexibility with back-saver sit-and-reach, and cardiovascular endurance (CVE) using the 20m PACER test. Hierarchal multiple regressions were used to measure associations between the HRF components and overall FMS and the FMS subtests: locomotor, object control and balance skills. Results show significant positive relationships between FMS and MS (R^2 = 0.25, β= -0.19), ME (R^2 = 0.11, β= 0.34), flexibility (R^2 = 0.13, β= 0.14) and CVE (R^2 = 0.17, β= 0.39), and an inverse relationship between FMS and body composition (R^2 = 0.25, β= -0.19). Furthermore, the data presented reinforces the position that the relationship between FMS and HRF is dynamic, and predominantly strengthens with age through the course of childhood. Findings suggest that developing FMS as a child may be important to developing HRF across childhood and into adolescence.

Keywords: Fundamental movement skills; FMS; health related fitness; HRF; physical activity.

4.2 Introduction

A multitude of research has sought to improve physical activity (PA) levels in an effort to promote health in children and adolescents (Fletcher, 2009). Fundamental movement skill (FMS) and health related fitness (HRF) are both purported to be linked with increased PA (Lubans et al., 2010; Cliff et al., 2009; Robinson et al., 2015; Barnett et al., 2009). FMS are the building blocks of more advanced, complex movements (Logan et al., 2018). They are comprised of three categories: locomotor (e.g. running and jump), object control skills (e.g. kicking and throwing) and stability skills (e.g. static balance) (Gallahue & Ozmun, 2006). FMS do not develop naturally over time and must be nurtured (Clark, 2007). When mastered and combined, they contribute to more complex skills allowing individuals the opportunity to be active through a variety of activities in which these skills are required. It could be assumed that any increase in PA would coincide with an increase in HRF (Stodden et al., 2014), as the simple act of moving more should logically impact fitness and strength levels.

Health related fitness (HRF) is made up of several components, cardiovascular endurance (CVE), muscular strength (MS), muscular endurance (ME), flexibility and body composition (Caspersen et al., 1985). CVE, MS, ME and body composition have been independently identified as factors that predict healthy outcomes throughout life such as reduced risk of cardiovascular disease, obesity, mental health and bone density (Pate et al., 2012; Ruiz et al., 2009). There is, however, little to suggest flexibility has any significant relationship with health outcomes (Casonatto et al., 2016). Given the varying strength of relationship between the HRF components and important health markers (Catuzzo et al., 2016), it would seem prudent to assess each component individually, rather than as part of an overall construct. All ways in which these components are developed should be investigated to inform future practice and intervention design. FMS is suggested to aid in the development of HRF components (Lubans et al., 2010; Stodden et al., 2014; Cattuzo et al., 2016), and research shows that adolescents with low FMS proficiency compare poorly in HRF status to those with higher FMS levels (Jaakkola et al., 2019). These findings warrant further examination of the relationship between FMS and HRF.

Research has consistently shown positive associations between FMS and HRF, but many studies choose to measure just one of the HRF components (CVE most commonly) as a proxy for the HRF construct (Cattuzzo et al., 2016). Others merge several components of HRF together as a composite score (Stodden et al., 2014), but there are disadvantages to looking at HRF as a singular construct considering flexibility has not shown links to positive health outcomes (Pate et al., 2012; Stodden et al., 2015). In addition, evidence remains inconclusive whether FMS and flexibility are associated, either positively or negatively (Cattuzzo et al., 2016). When looking at the relationship between FMS and the remaining HRF components, results demonstrate strong evidence of positive associations between FMS and CVE (Barnett et al., 2008), FMS and MS (Hands et al., 2009), FMS and ME (Erwin & Castelli, 2008), and an inverse association with body composition (Lopes et al., 2012). Notably, the associations between FMS and HRF components appear similar for both males and females (Cattuzzo et al., 2016). Stodden and colleagues suggest that the relationship between FMS and HRF are dynamic and strengthen with age, implying that the development of FMS may be a "*causal mechanism to promote either positive or negative trajectories of HRF as well as physical activity and body composition status across time*" (2008, p.232).

Participation in PA leads to positive health outcomes, and increased PA leads to increased levels of HRF (Fletcher, 2009). The link between positive health outcomes and most HRF components is clear, therefore the importance of improving HRF levels across childhood, and the methods to do so, should not be overlooked. Increased levels of FMS development leads to increased PA participation (Robinson et al., 2015), suggesting that increasing FMS proficiency may affect the HRF components (Cattuzzo et al., 2016; Stodden et al., 2014). There is a worldwide trend showing children and adolescents to be low in HRF and FMS competence (Belton et al., 2014; Hardy et al., 2010; Behan et al., 2019; Lubans et al., 2012). Considering this, exploring whether the relationship between FMS and HRF components are in fact dynamic is essential. Understanding how this relationship changes with age could be key to understanding what drives PA participation. The study reported here is unique in that it seeks to examine each individual component of HRF and its relationship with FMS in primary school aged children.

4.3 Methodology

Participants

As part of the national 'Moving Well-Being Well' physical literacy study, a cross-sectional sample of typically developing children were included in the final data set (n = 2098, 47% girls, age 5-12 years of age, mean age 9.2 ±2.04). The 44 participating schools (88% participation rate) were located in 12 counties across Ireland. Further detail on participant data is outlined in Behan et al. (2019).

Subjects were split into four age categories (age 5-6, age 7-8, age 9-10, and age 11-12), with descriptive data outlined in Table 1. Some of the HRF assessments (20m PACER and isometric plank hold) are not suitable for younger children and as such were only utilised with the two older age categories.

Ethical approval was obtained from the institutional Research Ethics Committee (DCU/REC/2017/029). Initial consent from the participating schools was granted from each school's principal, followed by parental consent, and age appropriate participant assent. Participants age and gender were collected through the consent forms and classroom questionnaires. All participants were allocated a unique code to ensure anonymity.

Measures

Motor competence was assessed using the Test of Gross Motor Development -3rd Edition (TGMD-3) (Ulrich, 2013). The TGMD-3 contains 13 FMS assessments, consisting of locomotor and object control skill subtests (Ulrich, 2013). The vertical jump, from the Victorian Fundamental Motor Skills manual (Department of Education Victoria, 1996, *Fundamental Motor Skills: A Manual for Classroom Teachers*, Melbourne: Education Department of Victoria) was added to the locomotor test battery. The vertical jump and the TGMD-3 are process based assessments, and assess the performance of components of the skills, rather than assessing the outcome of the skill. These are reliable and valid tests used widely throughout the literature (Cools et al., 2010).

The balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency 2 (BOT-2) Short Form was also included to measure the stability component of FMS (Bruininks, 2005; Rudd et al., 2015a). The BOT-2 Short Form is a motor competence battery (Deitz et al., 2009) and has proven validity and reliability (Deitz et al., 2009). This is a product based assessment, measuring the outcome of the skill rather than its performance (Deitz et al., 2009).

Body composition was measured using body mass index (BMI) and waist circumference (Cairney et al., 2010). Height and mass was measured using a stadiometer and a scale in accordance with standardised procedures (Meredith & Welk, 2010). Height was measured to the nearest 0.1cm and mass to the nearest 0.5kg, which allowed BMI to be calculated (BMI= weight (kg)/height (m^2)). Waist circumference was measured when participants were at minimal respiration and was taken at the highest point of the iliac crest (Gillum, 1999). Waist circumference was measured to 0.1cm.

Flexibility was assessed using the back-saver sit-and-reach test. This allows for both legs to be measured separately and can highlight any asymmetries in hamstring flexibility (Ruiz et al., 2006). Flexibility was measured to the nearest cm, with both sides assessed and the average score reported. The reliability and validity of the test has been widely reported (Meredith & Welk, 2010).

Muscle strength was obtained by measuring hand grip strength (Ruiz et al., 2006) with a hand dynamometer (Takei 5401 Digital model). After adjusting the dynamometer to the subjects required grip span (Ruiz et al., 2006), grip strength was assessed while participants were in a standing position with their arm fully extended. Both left and right hands were measured to the nearest 0.1kg, with the best scores on each being averaged to provide a total hand grip strength score. More details of the procedures and protocols are outlined in previous publications (Ortega et al., 2005).

Muscle endurance was measured through an isometric plank hold (Boyer et al., 2013). This test is thought to be particularly useful for younger children as it has shown that all achieve a higher than zero score (Boyer et al., 2013), in contrast to curl-ups or push ups reported in other studies (Meredith & Welk, 2010). Only participants over eight years of age were included in the plank test, as its not recommended for younger children (Boyer et al., 2013). The protocol required participants to hold a static prone position with just their forearms and toes touching the floor until failure with the score being recorded to the nearest second (See Boyer et al., 2013 for full procedures).

The 20m PACER test was used to assess CVE (Meredith & Welk, 2010). Again, only children over eight years of age participated in the 20m shuttle run, as this assessment is not recommended for younger children (Meredith & Welk, 2010). Participants run back and forth between two lines spaced 20m apart in time with an audible cue. If a participant fails to reach the line in time with the cue on two consecutive occasions, then they are deemed to have finished the test. The amount of shuttles completed are then used to calculate the VO_{2max} of each participant using formulas described by Leger and colleagues (1984). VO_{2max} is the maximal oxygen consumption available to a participant and is widely used in measuring CVE (Ruiz et al., 2006). More details on the procedure can be found in previous literature (Meredith & Welk, 2010).

Data Collection

The FMS data collection followed the protocols outlined by Ulrich (2013), the Victorian FMS Manual (1996), and Bruininks (2005), as described in Behan et al. (2019). The trained research team were required to achieve a 95% inter-observer agreement on a pre-coded data set, while blind to the coding conditions. The raw score for overall FMS was the sum of the locomotor, object control and balance subtests.

All participants completed a general warm up before any HRF testing. Instruction and demonstrations were delivered for each of the assessments, with BMI, waist circumference, flexibility, grip strength and the plank test all being assessed individually. Appropriate care was taken to the sensitivities of testing BMI and waist circumference. Children were assessed behind a screened area with same gender assessors, in line with the ethical guidelines set out by the institution. The 20m PACER test was conducted in groups of ten to 15 participants with three assessors in place, as per guidelines (Meredith & Welk, 2010).

An innovative iPad application was developed to collect the data used in this study, full details described in Behan et al. (2019). Data collection was carried out as per protocols outlined in the research (Bruininks, 2005; Boyer et al., 2013; Meredith & Welk, 2010; Ruiz et al., 2006; Ulrich, 2013), and when complete was uploaded to a secure server based on the university campus. This is in full compliance with the general data protection guidelines (GDPR) dictated by European law, and gained approval from the institutions ethics committee. The PACER test was not assessed using the application, and was conducted in the traditional pen and paper manner.

Statistical Analyses

SPSS 24 was used for all data analyses. Descriptive statistics were used to calculate the mean and standard deviation of each age category for the overall FMS score, including locomotor, object control and balance subtests, and each of the HRF components. Pearson's correlations were conducted to evaluate the relationships between the HRF components and overall FMS.

A multivariate analysis of covariance (MANCOVA) was performed to assess the relationships among FMS and HRF components across the four age categories. The dependent variables were the HRF components: BMI, Waist Circumference, Grip Strength, and Flexibility. The independent variable was the age categories (1 - 4) and the covariate was overall FMS. Across the two older age groups (independent variable), a second MANCOVA was performed to assess the relationships among overall FMS (covariate) and the HRF components: VO_{2max} and the plank test (dependent variables). Preliminary checks were conducted to ensure that there was no violation of the assumptions of normality, homoscedasticity, linearity homogeneity of variances, homogeneity of regression slopes, and reliable measure of covariate. Alpha was set at $p<0.01$.

Hierarchal multiple regressions were performed with all participants to assess the predictive ability of FMS competence (independent variable) to HRF components (dependent variables), after controlling for age and gender. Finally, additional hierarchal regressions were performed to understand the relative contribution of each of the three FMS subtests (independent variables) to each HRF component (dependent variables) across the four age categories, after controlling for the effect of gender. Alpha was set at $p<0.05$.

4.4 Results

Descriptive statistics indicate that overall FMS increased across age groups (Table 1). The three subtests reflect this with the exception of balance which decreased slightly in the 11-12 year old group. Similarly, most of the HRF components increased over time except flexibility which decreased with age.

Table 4.1. Descriptive statistics for the raw scores of the FMS and HRF components by age categories

	5-6 yrs M = 201, F= 161			**7-8 yrs M = 322, F= 294**			**9-10 yrs M = 316, F= 314**			**11-12 yrs M = 239, F= 200**		
Variables	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
Overall FMS	357	71.97	15.44	604	81.46	18.95	576	92.20	13.83	421	96.89	12.21
Locomotor	360	38.18	9.26	605	42.55	10.39	583	46.83	8.19	424	47.88	7.39
Object Control	359	28.40	8.54	609	32.88	10.39	618	38.36	7.69	433	42.03	6.57
Balance	362	5.28	2.09	616	5.84	2.29	630	6.87	1.79	439	6.75	1.94
HRF Components												
BMI	365	16.30	2.03	620	16.54	2.56	617	17.82	3.38	439	19.13	3.86
Waist Circ.	357	53.71	5.14	609	55.48	6.27	630	60.85	9.67	436	65.02	9.83
Grip Strength	353	8.31	2.39	604	10.04	2.64	614	12.94	3.00	427	15.93	3.75
Flexibility	302	13.12	6.01	603	11.79	6.27	614	10.99	6.59	404	9.71	7.04
VO_{2MAX}	n/a	n/a	n/a	n/a	n/a	n/a	567	49.15	5.72	424	48.53	6.53
Plank	n/a	n/a	n/a	n/a	n/a	n/a	516	77.38	58.74	382	79.70	53.53

The matrices in Table 2 outline the relationships between the HRF components and overall FMS. Significant correlations, ranging from weak to moderate (r = 0.093-0.49), were found between overall FMS and each HRF component, with the exception of BMI. These correlations varied across the age categories, with waist circumference, VO_{2max} and the plank test all showing the relationship strengthening with age.

Table 4.2. Correlation matrices for HRF components and overall FMS by age categories. (p<0.05, ** p<0.001)*

	BMI	WAIST CIRC.	GRIP STRENGTH	FLEXI-BILITY	VO_{2MAX}	PLANK
5-6 YEARS OF AGE						
BMI	-					
WAIST CIRC.	0.071	-				
GRIP STRENGTH	0.027	0.160**	-			
FLEXIBILITY	0.052	-0.151**	0.061	-		
OVERALL FMS	0.017	0.002	0.253**	0.144*	n/a	n/a
7-8 YEARS OF AGE						
BMI	-					
WAIST CIRC.	0.166**	-				
GRIP STRENGTH	0.05	0.213**	-			
FLEXIBILITY	-0.072	-0.183**	0.049	-		
OVERALL FMS	-0.012	-0.117**	0.266**	0.095*	n/a	n/a
9-10 YEARS OF AGE						
BMI	-					
WAIST CIRC.	0.093*	-				
GRIP STRENGTH	0.135**	0.318**	-			
FLEXIBILITY	-0.012	-0.223**	-0.03	-		
VO_{2MAX}	-0.036	-0.296**	0.138**	0.027	-	
PLANK	-0.021	-0.200**	0.085	0.247**	0.202**	-
OVERALL FMS	-0.022	-0.211**	0.245**	0.097*	0.317**	0.292**
11-12 YEARS OF AGE						
BMI	-					
WAIST CIRC.	0.192**	-				
GRIP STRENGTH	0.014	0.216**	-			
FLEXIBILITY	-0.058	-0.170**	0.024	-		
VO_{2MAX}	-0.038	-0.426**	0.097*	0.041	-	
PLANK	-0.02	-0.357**	-0.064	0.207**	0.321**	-
OVERALL FMS	-0.088	-0.311**	0.063	0.082	0.489**	0.400**

The first MANCOVA showed a significant effect for the covariate overall FMS across age categories ($F(12,4744.12) = 92.03$, $p < 0.001$, partial eta squared = 0.169) on all dependent variables (BMI, Waist circumference, grip strength and flexibility). The results showed that each of the dependent variables changed significantly through the various age categories, and the effect sizes varied from weak to strong: BMI ($p < 0.001$, partial eta squared = 0.109), waist circumference ($p < 0.001$, partial eta squared = 0.239), grip strength ($p < 0.001$, partial eta squared = 0.343) and flexibility ($p < 0.001$, partial eta squared = 0.036). The results also showed a moderate strength relationship between the covariate (overall FMS) and the dependent variables (BMI, waist circumference, grip strength and flexibility) while controlling for the independent variable (age categories) ($F(4,1793) = 46.87$, $p < 0.001$, partial eta squared = 0.095).

The second MANCOVA again reported a significant effect for FMS across the two older age categories ($F(2,810)=11.729$, $p<0.001$, partial eta squared = 0.028) on dependent variables (VO_{2max} and Plank Test). Significant changes were observed in VO_{2max} across the age groups ($p < 0.001$, partial eta squared = 0.028), although the effect size was weak. No significant changes were observed in the plank test results ($p = 0.296$, partial eta squared = 0.001). The results showed a strong relationship between the covariate (overall FMS) and the dependent variables (VO_{2max} and plank test) while controlling for the independent variable (age categories) ($F(2,810) = 113.12$, $p < 0.001$, partial eta squared = 0.218). The results from both MANCOVA's showed that FMS significantly interacts with the HRF components and that the relationship is dynamic across the age categories. This prompted further investigation of the relationships, including exploring the associations between the HRF components and the FMS subtests.

Hierarchal multiple regressions including the full sample were used to assess the ability of overall FMS to predict the HRF components scores after controlling for age and gender (Table 3). Age was entered at Step 1, and had a significant effect on BMI, waist circumference, grip strength and flexibility, ranging from explaining 2.6% of the variance in flexibility to 48.3% in grip strength. Age had no predictive qualities towards VO_{2max} or the plank test. Step 2 controlled for gender, which had a significant effect on waist circumference (22.4%), grip strength (48.8%), flexibility (11.5%) and VO_{2max} (2%). Gender did not predict BMI ($R^2 = 0.112$, $F(2,1948) = 122.73$, $p = 0.942$, $\beta = -0.002$) or the plank test scores ($R^2 = 0.002$, $F(2,829) = 0.91$, $p = 0.525$, $\beta = 0.022$). After entry of overall FMS at Step 3, the total variance explained by the model as a whole varied for each individual HRF component. Overall FMS accounted for no significant variance in BMI ($R^2 = 0.113$, $F(3,1947) = 82.67$, $p = 0.123$, $\beta = -0.038$), but accounted for a significant variance in each of the remaining HRF components, including 25.1% variance in waist circumference ($R^2 = 0.251$, $F(3,1928) = 214.9$, $p < 0.001$, $\beta = -0.189$), 50.2% in grip strength ($R^2 = 0.502$, $F(3,1903) = 638.97$, $p < 0.001$, $\beta = 0.136$), and 12.9% in flexibility ($R^2 =$

0.129, $F(3,1838) = 90.42$, $p < 0.001$, $\beta = 0.137$). The total variance explained by the model as a whole showed FMS had an effect of 16.5% on VO_{2max} ($R^2 = 0.165$, $F(3,918) = 60.38$, $p < 0.001$, $\beta = 0.393$) and 11.4% on the plank test ($R^2 = 0.114$, $F(3,828) = 35.66$, $p < 0.001$, $\beta = 0.344$).

Table 4.3. Multiple Regression Analyses for overall FMS to the HRF components

		F	**R^2**	**BETA**
BMI				
STEP 1	Age	245.57**	0.112	0.335**
STEP 2	Gender	122.73	0.112	-0.002
STEP 3	Overall FMS	82.67	0.113	-0.038
WAIST CIRC				
STEP 1	Age	534.26**	0.217	0.466**
STEP 2	Gender	278.77**	0.224	-0.086**
STEP 3	Overall FMS	214.90**	0.251	-0.189**
GRIP STRENGTH				
STEP 1	Age	1777.87**	0.483	0.695**
STEP 2	Gender	908.05**	0.488	-0.074**
STEP 3	Overall FMS	638.97**	0.502	0.136**
FLEXIBILITY				
STEP 1	Age	49.66**	0.026	-0.162**
STEP 2	Gender	119.07**	0.115	0.297**
STEP 3	Overall FMS	90.42**	0.129	0.137**
VO2MAX				
STEP 1	Age	0.74	0.001	-0.028
STEP 2	Gender	8.76**	0.019	-0.134**
STEP 3	Overall FMS	60.38**	0.165	0.393**
PLANK				
STEP 1	Age	1.41	0.002	0.041
STEP 2	Gender	0.91	0.002	0.022
STEP 3	Overall FMS	35.66**	0.114	0.344**

Additional hierarchal multiple regression analyses were conducted to explore if any of the three FMS subtests contributed significantly to the individual HRF components across the four age categories. The original regressions showed no significant findings with BMI, as a result this component was discarded from further analyses. Locomotor, object control and balance skills were all shown to be significant in each of the remaining HRF components (Table 4). For waist circumference, only the locomotor and balance subtests showed a significant inverse relationship, with locomotor increasing in strength from the 9-10 year old ($p < 0.001$, $\beta = -0.17$) to the 11-12 year old ($p < 0.001$, $\beta = -0.222$) age categories. Object control was a significant factor in grip strength in all age categories bar the oldest. All three FMS subtests were found to have a significant association in the 9-10 year old age group for flexibility, however, while locomotor ($p = 0.039$, $\beta = 0.11$) and balance ($p < 0.001$, $\beta = 0.198$) continued to be significant in the oldest category, object control did not ($p = 0.289$, $\beta = -0.058$). All subtests were significant for VO_{2max} in the 9-10 year old group, with the relationship strengthening into the older age group in locomotor ($p < 0.001$, $\beta = 0.219$) and object control ($p < 0.001$, $\beta = 0.277$). Balance was not significant ($p = 0.08$, $\beta = -0.08$) in the oldest group. Lastly, the plank test showed the locomotor subtest to be significant and the relationship strengthened from the 9-10 year old ($p = 0.042$, $\beta = 0.109$) to 11-12 year old groups ($p < 0.001$, $\beta = 0.268$). Full results of these relative contributions can be found in Table 4.

Table 4.4. Regression analyses for FMS subtests, locomotor, object control and balance skills, to the HRF components

		WAIST CIRC			GRIP STRENGTH			FLEXIBILITY			VO_{2MAX}			PLANK		
	Independent Variables	F	R^2	β	F	R^2	β	F	R^2	β	F	R^2	β	F	R^2	β
5-6 YEAR OLDS	Gender	0.01	0.000		3.25	0.009		15.32**	0.049		n/a	n/a	n/a	n/a	n/a	n/a
	FMS Subtests	0.76	0.009		7.8**	0.083		5.72	0.072		n/a	n/a	n/a	n/a	n/a	n/a
	Locomotor			0.066			0.023			0.044	n/a	n/a	n/a	n/a	n/a	n/a
	Object Control			-0.01			0.237**			0.096	n/a	n/a	n/a	n/a	n/a	n/a
	Balance			-0.103			0.088			0.068	n/a	n/a	n/a	n/a	n/a	n/a
7-8 YEAR OLDS	Gender	1.85	0.003		1.92	0.003		56.16**	0.087		n/a	n/a	n/a	n/a	n/a	n/a
	FMS Subtests	4.29**	0.028		13.29**	0.083		16.81*	0.102		n/a	n/a	n/a	n/a	n/a	n/a
	Locomotor			-0.022			0.063			0.078	n/a	n/a	n/a	n/a	n/a	n/a
	Object Control			-0.022			0.249**			-0.032	n/a	n/a	n/a	n/a	n/a	n/a
	Balance			-0.136**			-0.011			0.088	n/a	n/a	n/a	n/a	n/a	n/a
9-10 YEAR OLDS	Gender	14.69**	0.025		7.49**	0.013		49.86**	0.081		3.0	0.006		1.47	0.003	
	FMS Subtests	19.57**	0.121		11.54**	0.077		19.68**	0.123		16.82**	0.116		11.85**	0.093	
	Locomotor			-0.17**			0.057			0.17**			0.144**			0.109**
	Object Control			0.014			0.227**			-0.099*			0.187**			0.21**
	Balance			-0.218**			0.007			0.114**			0.115**			0.07
11-12 YEAR OLDS	Gender	2.84	0.007		2.78	0.007		64.37**	0.141		17.94**	0.042		0.34	0.001	
	FMS Subtests	14.24**	0.122		1.42	0.014		24.14**	0.199		32.17**	0.241		19.16**	0.174	
	Locomotor			-0.222**			-0.007			0.11*			0.219**			0.268**
	Object Control			-0.082			0.045			-0.058			0.277**			0.07
	Balance			-0.134**			0.066			0.198**			0.08			0.198**

4.5 Discussion

This study explored relationships between the components of HRF and FMS in Irish primary school children. Results showed that the relationship is dynamic, and predominantly strengthens with age, with the various FMS subtests contributing to each HRF component in different ways. While numerous prior studies have looked at the relationship between motor competence and a single component of HRF (Cattuzzo et al., 2016; Ortega et al., 2008), this research assessed the relationship between each independent HRF component and FMS.

Before examining the relationship between FMS and HRF, it is worthwhile to look at the HRF results alone, as there is very little data reporting the fitness status of Irish children. Perhaps the most commonly reported is BMI, and the mean BMI results presented here will place both Irish boys and girls in the 'Healthy Fitness Zone' (HFZ) in the FITNESSGRAM (Welk et al., 2007), as well as categorising the participants as being within the healthy weight status thresholds outlined by the World Health Organisation (WHO) (de Onis et al., 2007). In relation to CVE, the results presented in Table 4.1 place Irish children well above the VO_{2max} thresholds to achieve a HFZ status (40.1 – 40.3) in the FITNESSGRAM (Welk et al., 2007). The mean grip strength scores show the 9 to 10 year old boys would be placed in the 20th percentile, and girls in the 40^{th} percentile of the EUROFIT tool, with the 11 and 12 year old group both lying the 10^{th} percentile (Tomkinson et al., 2018). In assessing muscular endurance, the results also show the Irish cohort to be well above average in the isometric plank hold, with the scores presented here for the 9 to 10 year olds scoring higher than the average 12 year olds reported by Ervin et al. (2014). Overall, the results show the participants in this study are above average in all HRF components.

Considering body composition, this study measured both BMI and waist circumference. A recent systematic review showed the majority of studies examining FMS and BMI indicate a significant inverse relationship (Cattuzzo et al., 2016). In the current study, however, age was the only factor that predicted BMI (R^2 = 0.11, β= 0.34), although this may be due to the wide age range assessed in this sample. The second measure of body composition used in this study, waist circumference, did however show a significant inverse relationship with FMS accounting for 25% of the variance (R^2 = 0.25, β= -0.19). It should be noted that age (R^2 = 0.22, β = 0.47) and gender (R^2 = 0.22, β = -0.09) were also significant predictors. Increased body mass could be detrimental to the proficiency of FMS that involves movement of the entire body (Okely et al., 2004), e.g. locomotor skills such as running or jumping. Looking at the results of the second round of regression analyses, where the participants were broken into four age categories, the strength of the relationship between locomotor skills and waist circumference increased from the 9-10 year old age group (β = -0.17) to the 11-12 year old age group (β = -0.22). Any increase of mass could also lead to inefficient movement patterns, in turn having a negative impact on performance of object control skills (Stodden et al., 2014). Unhealthy weight status has a negative impact on PA participation (D'Hondt et al., 2012), which obviously could lead to negative effects on FMS proficiency and HRF development. Conversely, the development of FMS and a healthy weight status could promote a "*positive spiral of engagement'*" leading to enhanced health benefits (Stodden et al., 2008, p.232).

Looking at the relationship between waist circumference and FMS, the results show gender only played a significant role at the 9-10 year old age group, albeit accounting for just 2.5% of variance. This could be due to maturation effects. Females generally reach puberty earlier than males and centralisation of body fat normally doesn't occur until puberty (Malina, 2014). These results suggest that efforts to improve FMS proficiency in young children could indirectly improve their body composition status in later years as it will lead a more active lifestyle due to an increase in motor competence.

There were significant associations between FMS and both the MS and ME components of HRF. Overall FMS predicted 50.2% of variance in grip strength (MS) within the full sample, with gender and age also being significant predictors. Object control skills were the only significant contributor of the FMS subtests across the three youngest age categories (Table 4). It is interesting to note both gender and object control skills become insignificant in the oldest age group. Looking at the progression of FMS proficiency levels depicted in Table 1, one wonders if the slowdown in development of FMS proficiency from the 9-10 year old to the 11-12 year old group is reflected in the lack of significant findings regarding grip strength (MS) in the oldest age group. ME is only significantly predicted by overall FMS (R^2 = 0.11, β = 0.34). The locomotor skills association with the plank test increased from the 9-10 year olds group (β = 0.11) to the 11-12 year old group (β = 0.27), as do the balance skills (β = 0.07 to 0.2). Conversely, object control skills were not significant in the oldest group. These results suggest that FMS, particularly locomotor and balance skills, and ME are directly related. One possible reason for this link could be involvement in sport, as sport participation is known to improve levels of MS and ME, particularly those which involve ballistic skills, i.e. throwing, kicking, and jumping, as they demand high levels of physical effort (Catuzzo et al., 2016).

The findings elucidated above, however, would challenge the hypothesis that only object control skills have a significant impact on HRF (Stodden et al., 2014). Looking at the relationship between FMS and CVE, results show overall FMS predicted 16.5% of VO_{2max} score. The second round of regressions showed that gender only became significant in the oldest age group. Both locomotor and object control association with VO_{2max} increased from the 9-10 year old to the 11-12 year olds age groups (Table 4). It is accepted that activities which increase FMS proficiency generally require high levels of movement which in turn will develop CVE (Hands et al., 2009), so while these results could be expected, it is interesting to note that the relationship strengthened with age. The results would suggest that increased fitness levels are related to both locomotor and object control skills, and not just object control skills as proposed by Stodden et al. (2014). It is clear, from these findings and previous research, that increases in motor proficiency are associated with higher levels of CVE in children and adolescents (Catuzzo et al., 2016; Barnett et al., 2008; Lubans et al., 2012; Hands, 2009).

Overall FMS showed a positive association with flexibility that increased across age, but gender also exerted a strong influence, with females demonstrating higher proficiency. There is limited research examining the relationship between FMS and flexibility, but the few that exist show similar findings as reported here (Erwin & Castelli, 2008; Catuzzo et al. 2016). These results, however, showed that the association only becomes significant in the older age groups. Understanding that flexibility does not have a clear association with positive health outcomes (Casonatto et al., 2016), the benefit of measuring flexibility in the traditional manner in children could be called into question, particularly when considering interventions to promote health.

Conclusion

Overall the results of this study demonstrated evidence that motor competence is indeed associated with the HRF components, although the relationships are complex. Stodden and colleagues (2014) propose that this relationship is dynamic, and that the associations strengthen with age. While Stodden et al. (2014) combined the HRF components as a single construct in their model, the results put forward in this research suggest that the relationship between FMS and the individual HRF components are indeed dynamic, with some components playing a more important role than others. The results suggest that improving locomotor and balance skills in children could improve body composition, while targeting object control skills can improve MS over time. Developing proficiency in overall FMS could lead to increased CVE and ME as children get older. The evidence linking body composition, CVE, MS and ME to health are clear (Ortega et al., 2008), and it is well established that increases in PA also leads to improved health status (Fletcher, 2009). Combined with the growing body of research showing that increased FMS proficiency leads to increased PA participation (Cliff et al., 2015), it seems clear that future interventions should focus on developing FMS and HRF components. This may prove to be a catalyst in promoting lifelong engagement in PA and thus improvements in health status.

Limitations

This study employed an extensive range of FMS assessments, allowing for greater detail in analysis of the intricate relationships between FMS and HRF components compared to previous studies. In addition, the large sample size allows for generalisability. That being said, given the cross sectional nature of the design, these results cannot confirm causal pathways. While the research team received extensive training in all assessments, only the inter-rater reliability of the FMS assessments were reported here. Future studies should consider equivalent checks are completed on the reliability of measurement for the HRF measures. In addition, the FMS and HRF assessments employed are human movements and can be affected by physiological (Cattuzzo et al., 2016), maturational (Hands et al., 2009), psychological (Robinson et al., 2015), and environmental constraints (Özdirenç, Özcan, Akin, & Gelecek, 2005). Future research should focus on longitudinal designs that look at the development of FMS and HRF components, and they effects they may have on other variables. To that effect, a major confounder not measured in this study is PA. Any future work examining the relationships between FMS and HRF should also seek to objectively measure PA in order to examine the effect, if any, the dynamic relationship may have on PA participation.

Link from Chapter 4 to Chapter 5

The results presented in chapter 4 suggest that the relationship between FMS and the HRF components are dynamic and strengthen with age. While this has been documented in previous research (Stodden et al., 2014), it is the first time that a broad range of FMS was compared to each of the HRF components. The findings show that developing FMS at a young age could lead to increases in positive HRF status when older. This thesis has discussed the link between FMS and PA widely thus far, and the results outlined in chapters 3 and 4, along with other research, depict low levels of HRF and FMS throughout Ireland (Belton et al., 2014; Bolger et al., 2018; Kelly et al., 2018; O' Brien et al., 2016). The need to intervene and promote FMS development in young children in order to promote positive health outcomes later in life is clear.

The design and development process of the Moving Well-Being Well (MWBW) intervention is outlined in the next chapter. While I made a very significant contribution to the design and development of the intervention, as well a substantial contribution to co-authoring the paper presented Chapter 5, I must point out that I am not the lead author on the paper. As evident from the position of authors outlined on the study title page, my contributions were second only to those of the lead author, Dr Johann Issartel. While I contributed to both the introduction and discussion sections of the study, the bulk of my specific contributions were to the methodology and results section, particularly around the participant data, data collection, and all statistical analyses. It is included in this thesis so that the reader can gain a deeper understanding relating to the MWBW intervention program globally.

The intervention is underpinned by both the theory of constraints and self-determination theory, and is designed using the comprehensive framework outlined by the behaviour change wheel (Michie, van Stralen, & West, 2011). Multicomponent interventions that are underpinned by relevant theoretical frameworks have proven the most successful in previous research (Craig et al., 2008; Kriemler et al., 2011). The MWBW intervention contains several components, including family, community, active classroom, teacher training, and external provider components, all of which contain a strong focus on FMS development. Chapter 5 aims to outline the development of the MWBW intervention, including the rationale behind the chosen frameworks, why we feel there is a need for yet another intervention, and how the components will be implemented on a practical level.

Chapter 5: Development of a ‘refraction’ framework to underpin design of the Moving Well-Being Well physical literacy intervention

Manuscript submitted as: Development of a refraction framework to underpin design of the Moving Well-Being Well physical literacy intervention

International Journal of Behavioural Nutrition and Physical Activity – submitted Sep 2019

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5.1 Abstract

Physical literacy (PL) is a multifaceted construct and is seen as a means of engaging children and youth in physical activity at a societal level. Initiatives aiming to increase PL must be encouraged. In order for an intervention to be effective, they must be based on evidence and underpinned by a relevant theoretical framework. Given the paucity of empirical evidence concerning PL, this paper incorporates results from a cross sectional study utilising valid assessment of components of PL. This allows for greater understanding of the PL landscape, and provides baseline measures in which to measure progress.

This study designs and develops a PL intervention that marries the theory of constraints and self-determination theory, in order to change the direction of the learner's movement experiences towards more positive movement experiences. When applied, the intervention considers adapting constraints relating to the learner, task, and environment, with the intention of supporting a motivational climate, leading to positive movement experiences, and ultimately, impactful behavioural change over time. The Behavioural Change Wheel (BCW) is employed as a mapping framework for this intervention, to ensure the intervention is evidence based and suitable for the target population.

The Moving Well-Being Well intervention is designed as an evidence-based approach, grounding its content on the requirements of Irish children, with regard for the school and community environment. The intervention mapping framework, through the lens of the BCW, will support the development process, however it is the marriage between the TOC and SDT that i) supports the overall design and implementation of the intervention, ii) guides the interpretation of the results and iii) assists the reflection and future directions of the intervention. The holistic approach to intervention design presented in this study supports the interventionist in targeting a change in PL of Irish children, taking into consideration their motivation and surrounding environmental context.

5.2 Introduction

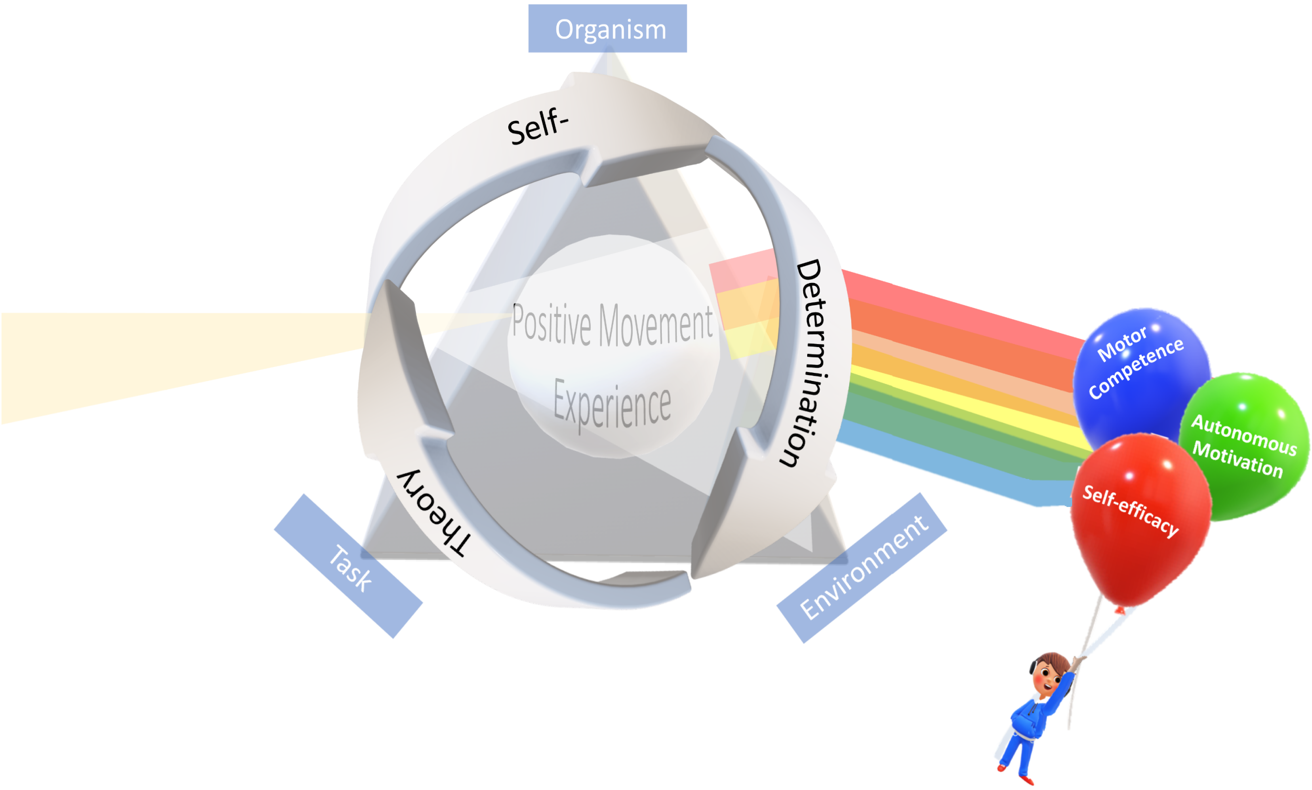
Utilisation of the term Physical Literacy has grown exponentially in the last 10 years discussed in small community groups, schools, universities, up to policy makers with unprecedented societal impact. The term Physical Literacy has now been introduced by the United Nations Educational, Cultural, and Scientific Organization (2015) as a core tenet in the physical education framework. The definition and conceptualisation of physical literacy still requires clarity, as there are various perspectives (Shearer et al., 2018; Edwards, Bryant, Keegan, Morgan & Jones, 2017). UNESCO define physical literacy as the ability, confidence, and motivation to engage in life-long PA, however there is a more commonly accepted consensus statement in academic literature that expands physical literacy to the "motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life". At the core of physical literacy is an acknowledgement that movement skill is not enough. That is, a physically literate person also has the motivation and confidence to engage in a wide array of physical activities, which foster enjoyment and an improved sense of self through movement experiences.

The term Physical Literacy is now 'in vogue' and resonates well in the research community whilst also having a growing impact 'on the ground' with practitioners. The increased popularity of this construct amongst researchers, coaches and teachers seems to indicate that a variety of people potentially grasp its meaning, opening the door for its manipulation and implementation. However, physical literacy is a complex construct and as such, there is a risk of misinterpretation and misrepresentation of its nature leading to potentially limited (or negative) impact on targeted groups. Essentially, teachers, coaches etc., require support and guidance to foster physical literacy 'on the ground' in an applied way. The construct of physical literacy, as a holistic approach to tackle a given potential problem, is appealing. However, when choosing this approach, caution needs to prevail at each point, from -A- the onset of a given project when choosing the measurement to objectively capture the needs (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009) to -Z- the implementation of the proposed solution (Keegan et al., 2019). This article is concerned with mapping the design, development and implementation of a physical literacy intervention starting from the first aspect: measurement. Indeed, the measurement of physical literacy determinants facilitates a pathway to understanding how to develop the intervention to maximise its efficiency (Gilmore & Campbell, 2005). This approach is embedded in the socio ecological model providing evidence that "*determinants are causally related to the behaviour and environmental conditions*" (Bartholomew, Loukas, Jowers, & Allua, 2006, p231). The proposition is to consider i) what are the components a learner needs to work on? ii) how should they be measured? And, iii) what is the interrelationship between the individual and their environment? These questions are to be followed by a decision on how to intervene. Several research groups have debated how to best measure physical literacy and its components, with questions still arising as to what might constitute an appropriate method of collecting empirical data for the study of physical literacy (Cairney, Veldhuizen, et al., 2018; Corbin, 2016; Edwards et al., 2017). Previous pragmatic approaches have attempted to capture and measure physical literacy, but have prioritised the physical domain (Tremblay, Longmuir, et al., 2018). Other measure/assessment attempts have adopted simplistic and linear methods that do not capture the concept of physical literacy (Edwards, 2017). In contrast, the PLAY tools (Physical Literacy Assessment in Youth), prove more promising, but while novel and aligned with the physical literacy consensus statement, it requires further psychometric testing. Given the paucity of empirical evidence concerning physical literacy, this study proposes incorporating validated measurements that align with the holistic philosophy of physical literacy as a more suitable method of assessment, the results of which could be utilised to inform physical literacy intervention design.

To that end, the assessment required in the context of this intervention development should be framed around the discrepancy between what is currently in place and what should be in place (Gilmore & Campbell, 2005). Such an exercise has never been conducted in the primary school setting in Ireland. Indeed, there is a dearth of understanding of Irish children's physical literacy levels, particularly at a component level. The approach taken in this study is to implement a formative evaluation of physical literacy components in order to better understand the determinants of health behaviour. This included a gathering of information about the participants, covering all components of the physical literacy construct. Gathering of information about the targeted population is essential (see method section) but not enough. That is, in order to have an impact on a child's behaviour we also need to consider the environment around them and, the nature of the tasks they can avail in their environment. Interactions between these three levels of constraints marry well with the Theory of Constraints proposed by Newell (1986) which highlights that behavioural change, including the movement behavioural change, occurs from the interplay between the task, the individual and his/her environment. The dynamical interaction between these three constraints effectively shape a change in movement quality and efficiency. This ecological dynamics approach takes into account all ingredients affecting the performer within his/her environment. It must be highlighted that Newell (1986) named the person the "organism" as the functional and structural properties embodied in the person.

This terminology echoes well the "organismic psychology" (Ryan, 1995) angle of the self-determination theory where the performers are viewed as active organisms. Self-determination theory (SDT) presents as another crucial 'recipe' or framework for behavioural change. It proposes a multidimensional conceptualisation of motivation in which the types of motivations are of different quality, with self-determined (or autonomous) motivation types (intrinsic motivation and identified regulation) considered to be higher quality than less self-determined (or controlling) types of motivation (introjected and external regulation; Ryan & Deci, 2000). According to SDT, the quality of motivation is vital, with more autonomous forms of motivation facilitating learning, performance, higher interest and greater effort (Grolnick and Ryan, 1987; Kasser & Ryan, 1996). To foster said autonomous motivation three psychological needs are required: competence (i.e., self-belief in one's development of mastery), autonomy (i.e., choice is available in one's actions), and relatedness (i.e., a feeling of meaningful interaction with others). Interestingly, these psychological needs are also impacted by constraints, relating to the task and the environment. Thus, we propose the foundations of *positive movement experiences* and a positive change in behaviour potentially lie in a marriage between the TOC and, SDT where constraints relating to the organism (learner, performer etc.), the task (activity, etc.) and environment (equipment, feedback, instruction) are adapted, specifically in line with learner needs and their surrounding context. Moreover, when we get this adaption right, we can change the direction or 'refract' a learner's movement experiences towards more positive movement experiences and, more positive outcomes associated with physical literacy, including motor competence, autonomous motivation and self-efficacy. This crucial interplay between a Theory of Constraints and SDT is outlined in Figure 5.1.

Figure 5.1. 'Refracting' movement experiences and physical literacy outcomes by marrying Theory of Constraints and Self-Determination Theory



In an applied sense, this means that a physical literacy intervention could consider 1) adapting constraints relating to learner (organism), task and environment with the intention of supporting a motivational climate and positive movement experiences, leading to improved outcomes associated with physical literacy (e.g. motor competence, self-efficacy, autonomous motivation) and ultimately, impactful behavioural change over time. In this study we propose identifying constraints of the learner, at local level, by measuring psychological and physiological components associated with physical literacy whilst also identifying constraints of the local context, and school community. Results are to be utilised as inputs to inform design and development of an evidence-based intervention that aims to bridge the gap between research and practice and improve physical literacy levels of Irish children.

Both TOC and SDT will be considered as core pillars supporting the overall development of this intervention whilst also being underpinned by the intervention mapping framework (Michie, van Stralen, & West, 2011). This mapping framework should be viewed as a list of 'ingredients' guiding good practice (in an applied way) at a micro level, whereas the TOC and SDT should be viewed as supporting the overall rational informing the development, implementation and future evaluation of the intervention.

Intervention Mapping Framework

The National Institute for Health and Care Excellence (NICE) (2014) reports behavioural changes come from an interaction between three core components; an individual's capability, opportunity and motivation to perform and carry out that behaviour. At a macro level, this is in line with TOC and SDT as it considers the importance of the Individual's physical and psychological capability as well as opportunities afforded to them, including opportunities associated with the task and environment. This specific behaviour change framework is known as the Capacity-Opportunity-Motivation Behaviour (COM-B) model. A recent review of behavioural change literature identified 19 frameworks associated with behavioural change. These frameworks were then evaluated in relation to their coherence, comprehensiveness and links to models of behaviour (Michie et al., 2011). As no framework contained all three criteria, they were synthesised into the 'Behavioural Change Wheel' (BCW), with a COM-B model at its core (Michie et al., 2011). Crucially, the BCW offers a list of intervention 'functions' mapped onto behaviour change taxonomy and applied techniques to guide design of interventions aimed at changing behaviours (further outlined in the discussion). These functions essentially provide designers with a micro set of ingredients to inform development of evidenced-based interventions that carefully map, evaluate and foster both the task and environmental conditions in order to best support an individual's behavioural needs over time.

Accordingly, this paper discusses the design of an evidence-based physical literacy intervention, which, at a macro level, is underpinned by TOC and SDT. Determinants of physical literacy and, intervention functions of the behavioural change wheel are utilised to tackle constraints relating to the learner, the task and the environment with the explicit intention of supporting the development of physical literacy in children. More specifically, the intervention takes an evidence-based approach, grounding its content on the needs of Irish children, on the realities and constraints of an Irish context/environment and the school community setting. Results relating to the learner and context were identified via a cross-sectional study which evaluated Irish children and their surrounding environment through the lens of physical literacy. Thus, arming us with a significant amount of information to map out an optimum structure of the intervention.

This study's intervention design is significantly supported by the construct of physical literacy which points us to a list of determinants (motivation, confidence, knowledge & understanding) that require evaluation and development. In a first instance, it is essential to measure these core components and consider them in relation to the intervention functions so that we can evaluate and develop effective change over time. The intervention mapping framework, through the lens of the BCW, will support the development process, however it is the marriage between the TOC and SDT that i) supports the overall design and implementation of the intervention, ii) guides the interpretation of the results and iii) assists the reflection and future directions of the intervention.

5.2 Methods

Local context informing the structure of the intervention

In Ireland, as in most countries internationally, generalist primary school teachers are responsible for delivery of PE content (Fletcher and Mandingo, 2012). It is often cited that primary school teachers feel poorly prepared to teach PE programmes in a way that is truly meaningful to pupils, and positively impact lifelong participation in PA (Fletcher and Mandingo, 2012). While the generalist teacher is unquestionably best placed to deliver curricular content to their class in a child centred and integrated manner (Coulter, Marron, Murphy, Cosgrave, Sweeney, & Dawson, 2009), a difficulty arises when insufficient time for PE is available on an overcrowded initial teacher training curriculum to allow all primary teachers develop confidence and competence in delivering PE. Identifying, developing and implementing strategies to help improve generalist classroom teacher's confidence and competence in teaching PE is recommended as a feasible avenue for improving the quality of PE experiences at primary level (Fletcher & Mandingo, 2012).

Murphy and O'Leary (2012), highlight some of the issues faced by primary generalise teachers when exposed to traditional CPD. While an initial boost in motivation for teaching PE, and trying new things, is experienced following the traditional 'seminar day' of CPD, this motivation is subsequently washed out as teachers fall back into the daily challenges of school life (Murphy & O'Leary, 2012). In Ireland there is an acknowledged increasing trend towards the use of external providers in the physical education space in primary schools (Ní Chróinín & O'Brien, 2019). It is accepted that there is benefit in terms of 'added value' of external providers contributing to aspects of children's learning in PE at primary schools (Ní Chróinín & O'Brien, 2019), however the way in which this external provision is structured is critical if maximum benefit is to be obtained.

Research conducted by Ní Chróinín & O'Brien (2019) highlight that there is limited authentic partnership development and engagement between the primary school teacher and the external provider currently in Ireland. The classroom teacher generally views the external provider as 'the expert', and as a result, takes a 'back seat' when the external provider is delivering content- engaging and communicating minimally (Ní Chróinín & O'Brien, 2019).The classroom teacher without doubt can be considered the expert in the child, and generating a child centred and integrated class room experience (Coulter et al., 2009). Harnessing the primary school teacher's belief in their own expertise in child centred pedagogy, as matching that of an external provider's expertise in the subject specific content, may well provide a new opportunity for professional development in primary school physical education. Increased communication and involvement in pedagogical decision making with external providers have been highlighted as areas to be addressed when *'reconceptualising the relationship between classroom teachers and external providers'* in Ireland (Ni Choinin & O'Brien, 2019, pp 329).

Participants

Cross-sectional data were collected as part of a national physical literacy study 'Moving Well-Being Well'. In all, 50 schools were approached with 44 agreeing to participate. Participants (n=2098, 47% girls, ranging from 5-12 years of age, mean age 9.2 ±2.04) were recruited from these schools across twelve counties (56% rural, 44% urban) in Ireland. Data from typically developing children were collected March through June 2017 across the full primary school cycle. Ethical approval was obtained from the Research Ethics Committee of the institution (DCU/REC/2017/029). Parental consent and participant assent were obtained, and participants were assigned a unique ID code to ensure anonymity. Age and sex were collected through consent forms and questionnaires administered in the classroom. Full details of participants can be found in previously published work (Behan, Belton, Peers, O'Connor & Issartel, 2019).

Data Collection

FMS proficiency were measured using the Test of Gross Motor Development, 3rd edition (TGMD-3) (Ulrich, 2013), with the vertical jump from the Victorian Fundamental Motor Skills manual (Department of Education Victoria, 1996, *Fundamental Motor Skills: A Manual for Classroom Teachers*, Melbourne: Education Department of Victoria), and the balance subtest from the Bruininks-Oseretsky Test of Motor Proficiency 2 (BOT-2) Short Form added to the assessment battery. All procedures described in the literature were fully adhered to (outlined further in Behan et al., 2019).

The pictorial scale of perceived movement skill competence for young children (Barnett, Ridgers, Zask, & Salmon, 2015), which aligned with TGMD-3, was also administered. The pictorial scale of perceived movement skill competence assesses six locomotor (run, gallop, hop, skip, horizontal jump, and slide) and seven object proficiency skills (two-hand strike of a stationary ball, one-hand stationary dribble, kick, two-hand catch, overhand throw, forehand strike of a self-bounced ball, and underhand roll), based on the TGMD-3. Delivery of the pictorial scale of perceived movement skill competence replicated the process of Peers, Belton, Behan, O'Connor & Issartel (2019, *in press*), with the extensive protocol available in Barnett et al. (2015).

The quality of children's motivation was measured using two subscales of the Behavioural Regulation in Exercise Questionnaire which was adapted for primary school children (BREQ-adapted; Sebire, Jago, Fox, Edwards, & Thompson, 2013). The BREQ-adapted is consistent with self-determination theory definitions (Ryan & Deci, 2000), and has been shown to have good psychometric properties in children (Sebire et al., 2013). The BREQ-adapted captures multidimensional components of motivation with 3 questions per motivation subscale: intrinsic (α = .81) and identified (α = .73). Items were scored using a 5-point Likert-type scale: 1 (not true for me) to 5 (very true for me). Full details are outlined previously in Peers et al. (2019, *in press*).

Self-efficacy was assessed using the Physical Activity Self-Efficacy Scale (PASES) was employed in this study. This scale was adapted for primary school children into an 8-item single factor scale (Bartholomew et al., 2006), and is consistent with self-efficacy definitions (Bandura, 1977, 1982, 1997), having shown good psychometric properties in children (Bartholomew et al., 2006). Items were scored using a 3-point Likert-type scale with "No" (0), "Not Sure" (1), and "Yes" (2) as the three choices. Cronbach's alpha (Cronbach, 1951) coefficient for PASES in this study was good (α = .88).

To measure physical activity, children completed the PACE+ (Prochaska, Sallis, & Long, 2001), a validated and reliable measure for this age (Murphy, Rowe, Belton, & Woods, 2015). Children were given a definition (PA is any activity that increases your heart rate and makes you get out of breath some of the time) and examples of common physical activities. Children were asked how many days in the past week and in a normal week they were physically active (cumulative activity including sports, playing with friends, and walking to school, however excluding physical education class) for 60 min or more. As suggested by these authors the average number of days from the past week and typical week was used as an index of PA participation (Prochaska et al., 2001).

An additional form of PA measurement was undertaken on a subsample using pedometers. A Yamex pedometer with proven validity was utilised. All participants wore the pedometer on the right hip during waking hours for a period of 9 days. The first and last day were discarded to give a seven-day step measurement. Participants were asked to note on a diary sheet any times (and reasons) during each of the 9 days they had to remove the pedometer. Participants noted each evening the number of steps they took before resetting the device in advance of the following day.

It should be noted that while FMS and PC were measured across all participants, it was not possible to measure self-efficacy, motivation, and self-reported PA assessments in a younger cohort (5 – 8 years) as tools have yet to be validated for this age group. As such, the sample size for these parameters is smaller, with 860 children/participants (47.9% female, 10.37 ±1.18 years).

5.3 Results

Results presented in Tables 5.1, 5.2, 5.3 & 5.4 illustrate the changes over time, for each measurement, carried out in a cross-sectional study. Beginning with PA levels (Table 5.1), the 50th percentile range, in terms of steps counts, is higher than the minimum 10,000 recommended steps for children. Of note is the fact that children in the lowest percentile range tend to do less and less over time, whilst children in the highest percentile range do more and more, explaining a widening of the gap in PA engagement over time.

From the perspective of FMS, previous findings from the same sample have identified a distinct lack of mastery among Irish children (Behan et al., 2019). Indeed, results showed just over half of the participants (n = 2098, age range 5 – 12 years, 47% girls) had mastery or near mastery in locomotor skills (52.8%) and object control skills (54.8%), while 60.6% had achieved mastery or near mastery in balance skills. Table 5.2 presents proposed normative values of FMS and its subtests, locomotor, object control and balance, in the same sample. Values have been yielded for the entire primary school age range.

Table 5.3 presents proposed normative values of perceived competence (PC) in Irish children. Notably, there seems to be no ceiling effect in the PC scores. There is no change in the 50th percentile from age nine to twelve, with 50% of the sample still seven points off the top score achievable. Another point of interest is the wide spectrum of scores for each age group, with the difference from the 10th to 90th percentile ranging between 11 and 17.8 points. The PC locomotor subset shows a decline in the 90th percentile with age, and again the 50th percentile remains the same from the age of nine. The PC object control subset shows the score needed to achieve 50th percentile status remains the same from age six all the way through to twelve, with nearly all age brackets reporting the 90th percentile as the maximum score achievable.

Table 5.1. Proposed normative values per age for Irish children for average daily steps measured using a pedometer and average PA measured using the self-report scale.

	Age							
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**
n	0	29	39	43	41	25	26	17
Average Daily Steps								
10th	n/a	7440.8	8222.3	7200.5	6705.2	9311.5	8177.8	6501
25th	n/a	9484.4	10449.9	8616.9	10001.1	11457.3	10286.2	8434.8
50th	n/a	12925.5	11894.4	12004.8	12778.3	13157.5	14264.4	11729.4
75th	n/a	17193.7	15723.3	15347.8	14698.5	15591.3	18704.1	14583.8
90th	n/a	18933	19703.3	18797.5	19352	17150.1	23955.8	21324.1

	Age							
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**
n	**n/a**	**n/a**	**n/a**	**n/a**	271	232	230	153
Average PA (Self Report – number of days meeting the 60min/day of MVPA)								
10th	n/a	n/a	n/a	n/a	2.5	3	2.1	3
25th	n/a	n/a	n/a	n/a	3.5	3.5	4	4
50th	n/a	n/a	n/a	n/a	5.5	5	5	5
75th	n/a	n/a	n/a	n/a	6.5	6	6	6
90th	n/a	n/a	n/a	n/a	7	7	7	7

Table 5.2. Proposed normative values per age for Irish children of overall FMS, locomotor, object control and Balance

	Age							
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**
n	116	244	312	298	334	247	256	171
Overall FMS Percentiles, max score = 120								
10th	50.7	56	54	65	70.3	80.4	82	83
25th	59.25	65	71	76	83	90	89	89
50th	67	75	82	87	92	97	98	98
75th	75	85	92	95.5	100	104	106	105
90th	86.3	92	99	105	105	110	111.5	111
Locomotor Percentiles, max score = 58								
10th	23.6	26	27	33	34	39	39	37.2
25th	31	35	36	40	42	45	44	44
50th	36	41	43	45.5	48	49	49	49
75th	43	46	48	50	52	53	53	52
90th	46	50	52	54	55	56	56	56
Object Control Percentiles, max score = 54								
10th	17	17	17	22	27	29	33	33
25th	21	23	25.5	29	32	35	38	38
50th	26	29	33	34	38	41	43	43
75th	31	35	39	41	42	46	47	46
90th	37.3	41	43	47	46	48	50	49.7
Balance Percentiles, max score = 8								
10th	2	2	2	3	4	5	4	4
25th	3	4	4	5	6	7	6	6
50th	5	6	6	7	8	8	8	8
75th	6	7	8	8	8	8	8	8
90th	8	8	8	8	8	8	8	8

Table 5.3. Proposed normative values per age for Irish children of perceived competence, including locomotor and object control subtests.

	Age							
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**
n	116	244	312	298	334	247	256	171
Total Perceived Competence Percentiles, Max Score = 52								
10th	31.1	34	35	35	36	38	37	34.4
25th	34.8	37	39	39	40	41	41	40
50th	39	41.5	43	42	45	45	45	45
75th	45	46	46	46	48	47	48	48
90th	48.9	49	49	49	50	49	50	50
Locomotor Perceived Competence Percentiles, Max Score = 24								
10th	15	15	15	16	16	17	16	16
25th	15	17	17	17	18	19	18	18
50th	18	19	19	20	20	20	20	20
75th	21	21	21	21	22	22	22	22
90th	24	24	24	24	24	23	23	23
Object Control Perceived Competence Percentiles, Max Score = 28								
10th	16	17	18.4	17.8	19	20	19	18.4
25th	18	19	21	21	22	22	23	21
50th	21.5	23	23	23	25	25	25	24
75th	25	25	25	25	27	27	27	27
90th	27.9	28	28	28	28	28	28	28

Finally, Table 5.4 proposes normative values for physical self-efficacy and autonomous motivation in Irish children. Both tools use considerably smaller scales than FMS and PC, but still have notable differences between the percentiles. Physical self-efficacy from age nine to twelve appears to remain consistent, regardless of percentile. Despite the small scale for physical self-efficacy, the difference from the 10th to 90th percentile is considerable across all ages. The 90th percentile demonstrate the maximum score available for physical self-efficacy across all the ages. Meanwhile, autonomous motivation for the top 25% have encountered a ceiling effect, this remains consistently high from age nine to twelve. Autonomous motivation appears to decline in the 10th percentile with age. Considering the scale, the 50th percentile is relatively high in regard to autonomous motivation.

Table 5.4. Proposed normative values per age for Irish children of self-efficacy and autonomous motivation, using the Physical Activity Self Efficacy Scale (PASES) and Behavioural Regulation and Exercise Questionnaire (BREQ) – Adapted measurement tool.

	AGE			
	9	**10**	**11**	**12**
n	235	202	214	138
Self-Efficacy Percentiles				
10th	1.25	1.375	1.25	1.3625
25th	1.50	1.50	1.50	1.50
50th	1.63	1.75	1.75	1.75
75th	1.88	1.88	1.88	1.88
90th	2.00	2.00	2.00	2.00
Motivation Percentiles				
10th	3.83	3.67	3.50	3.50
25th	4.33	4.17	4.00	4.17
50th	4.67	4.67	4.50	4.67
75th	5.00	5.00	4.83	5.00
90th	5.00	5.00	5.00	5.00

Ultimately, results presented by Behan and colleagues (2019) pertaining to the poor levels of PA and low levels of FMS mastery essentially frame the discrepancy between what is currently in place and what should be in place, in an Irish PE context. That is, Irish children are lacking in movement competence, and thus, valuable components of what it means to be physically literate. Furthermore, proposed normative values outlined in our results relating to PC, self-efficacy and autonomous motivation, essentially provide designers, researchers, teachers and practitioners with a veritable list of physical literacy components, associated with Irish primary children, that require attention. Crucially, normative values just presented, also offer a point of reference to measure and compare progress over time. Ultimately, results are used as inputs to inform intervention design. The next step of this design process is to examine these results through 'mapping functions' associated with Behaviour Change Wheel.

Input of results through the behaviour change wheel

The BCW uses an eight-step process to design interventions (Figure 5.2). The first three steps are to assist researchers identify the specific behaviour(s) they wish to change.

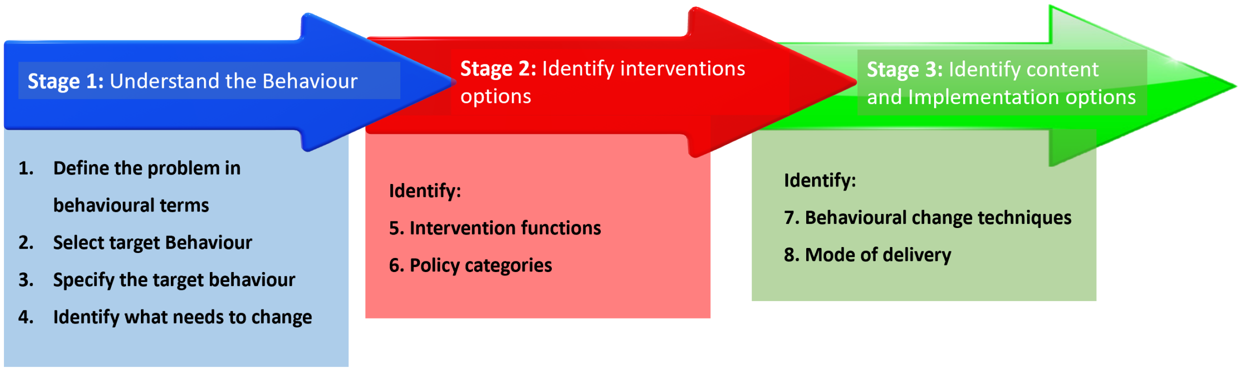


Figure 5.2. Behavioural Change Wheel Step by Step Method for Designing Behaviour Change Interventions (Michie et al., 2014)

When we input our results through these BCW steps, we come to the following outcomes: Starting with **stage one**, and the first step, the behavioural problem is that children are not getting enough PA (see Table 5.1). This increased sedentary lifestyle can cause negative health outcomes as a child, such as obesity, etc. Children with poor levels of PA at a young age tend to be less active throughout life and, with that, the negative health outcomes become more pronounced increasing risk of cardiovascular disease, obesity, diabetes, etc. The need to improve PA levels seems clear, however previous initiatives attempting this feat have fallen short. A fresh approach is needed. This research chooses to target the behaviours which drive PA, through the lens of PL. That is, research indicates that increased PL levels in children will foster an increase in confidence and motivation to be active, as well as the physical competence to partake in a range of activities (Whitehead, 2013). By developing PL, children are more likely to be active throughout life and thus benefit from the positive health outcomes associated with increased PA levels.

This brings us to the **second step** of the BCW - selecting the target behaviour – which we believe should be an overarching focus of increasing PL in children. **Step three** recommends that the target behaviour be specified. This is particularly important when the target is PL as we know that many practitioners ‘on the ground’ lack a clear understanding of the construct. Researchers define PL as the motivation, confidence, physical competence, knowledge and understanding to be active for life. Using this definition, the components of PL can be extracted: confidence, motivation, physical competence, knowledge and understanding. Table 5.5 completes the first stage of the BCW process by providing a detailed summary of components considered as target behaviours, and what exactly needs to change (**step 4**), as deciphered through the lens of the COM-B model. Table 5.5 also depicts the unit of measurement proposed in order to measure the efficacy of the intervention and the specific components of the Physical literacy construct that need to be changed.

Table 5.5. Links between the components of the COM-B model of behaviour to physical literacy and the measures employed to assess each domain

COM-B FEATURES	PHYSICAL LITERACY DOMAIN TARGET	IDENTIFY WHAT NEEDS TO CHANGE	UNIT OF MEASUREMENT
CAPABILITY			
PHYSICAL	Physical Competence	Low levels of FMS proficiency in children Teachers ability to assess motor competence	Test of Gross Motor Development 3rd Edition
PSYCHOLOGY	Motivation Confidence	Low levels of autonomous motivation towards PA in children Low levels of self-efficacy towards PA in children Low levels of perceived FMS competence in children	Physical Activity Self Efficacy Scale (PASES) Behavioural Regulation and Exercise Questionnaire (BREQ) – Adapted Pictorial Scale of Perceived Movement Skill Competence for Young Children
OPPORTUNITY			
SOCIAL	Motivation Confidence	Lack of opportunity to practice skills with peers and parents. Lack of opportunity to be instructed in FMS by a more knowledgeable other	Physical Activity Self Efficacy Scale (PASES) Behavioural Regulation and Exercise Questionnaire (BREQ) – Adapted Pictorial Scale of Perceived Movement Skill Competence for Young Children
PHYSICAL	Physical Competence	Lack of PA time in schools Lack of opportunities to practice physical skills in a safe environment	Test of Gross Motor Development 3rd Edition
MOTIVATION			
AUTOMATIC	Physical Competence Knowledge & Understanding	Lowly skilled children feeling insecure in practicing physical skills with their peers. Lack of understanding in how to perform skills, and the importance these skills have in being active.	Test of Gross Motor Development 3rd Edition MWBW Knowledge & Understanding Scale
REFLECTIVE	Knowledge & Understanding	Lack of understanding in the benefits of being active	MWBW Knowledge & Understanding Scale

5.4 Discussion and Intervention Design

The leitmotif of this article is to describe all characteristics leading to development of a PL intervention, entitled 'Moving Well-Being Well'. According to the BCW, Stage 2, Step 5 requires the identification of intervention functions through review of the evidence. We propose that it is crucial to consider evidence-based findings from the literature to guide this identification. In this study, we are well placed to effectively map intervention functions against actual findings from our cross-sectional study. In this way, the intervention is essentially personalised to meet the needs of Irish children in an Irish school community context.

Systematic reviews of school-based interventions provide evidence that the more effective strategies involve multiple components and are not solely limited to what can be achieved in a PE lesson (S. Kriemler et al., 2011; S Kriemler et al., 2011; Murillo Pardo et al., 2013; Salmon et al., 2007; Timperio et al., 2004)

To that end, school-based interventions offering a *family* component are cited as having positive effects on increased PA participation (Belton et al., 2014; Murillo Pardo et al., 2013). Interventions that include a *community* component are also deemed effective, with the suggestion that community organisations have the capacity to facilitate provision of activities in schools that are particularly attractive to students (Acker et al., 2011). Interventions that integrate activity breaks in the classroom (i.e., *Active classrooms*) as part of a whole school approach, have also gained traction in recent years and prove effective in increasing PA across the school day (Goh, Hannon, Webster, Podlog, Brusseau, & Newton, 2014; Martin & Murtagh, 2015).

Conversely, an examination of interventions targeting PA in children provides strong evidence that these programmes have only had a small effect (approximately 4 additional minutes) on children's overall activity levels, i.e. PA in and outside of school (Metcalf, Henley & Wilkin, 2012). Thus, in order to change behaviours and see an increase in Leisure Time PA (LTPA) we need to consider additional intervention components.

As previously mentioned, FMS development in children is widely reported to increase PA participation later in life (Barnett et al., 2009). Accordingly, we propose that an emphasis on skill development presents as a crucial 'ingredient' of behavioural change and note that, FMS can be targeted effectively as part of rounded PE programme (David Stodden et al., 2008). In summary, a multi-component intervention is required to facilitate real change in PL (S. Kriemler et al., 2011; Murillo Pardo et al., 2013; Salmon et al., 2007; Timperio et al., 2004). This includes a targeted effort to improve FMS, particularly in the PE setting, in order to equip children with the confidence and basic skill levels needed to partake in PA beyond the school setting and ultimately, throughout the life course (Stodden et al., 2008). Interventions should include components targeting active breaks, active classrooms, structured and focused PE, as well as engaging the family and the community (Acker et al., 2011). However, whilst research suggest that these components are an ideal, some may not currently be feasible in an applied sense 'on the ground'. We propose that it is crucial for interventions to be evidence-based and consider barriers that require negotiation as well as available facilitators, in order to bridge the gap between research and practical application.

Ultimately, the BCW framework provides an effective lens with which to view design and develop of an evidence-based intervention. It proposes a number of intervention functions to consider including: education, persuasion, training, enablement, and environmental restructuring outlined in more detail in Table 5.6. Accordingly, features of an evidence-based intervention include a continuous professional development (CPD) module, development of resources, and collaboration with professional bodies. Further, the BCW framework identifies overarching 'observable, replicable and irreducible' components known as behavioural change techniques (Michie et al., 2011a). These are considered the 'active ingredients' utilised to change behaviour. Active ingredients implemented in the Moving Well-Being Well intervention are outlined in Table 5.6 (Michie et al., 2011a).

Table 5.6. 'Active Ingredients' of the Moving Well-Being Well Intervention: Intervention functions mapped onto behaviour change taxonomy and applied techniques (i.e. Stage 3, Step 7)

INTERVENTION FUNCTIONS	DEFINITION	PHYSICAL LITERACY FRAMEWORK INTERVENTION
EDUCATION	Increasing knowledge or understanding	Coaches provided with information intervention need and delivery Teachers provided with information on benefits of FMS and best practice on how to develop confident movement via a mastery/SDT framework. Children provided with information about the benefits of PA, looking to develop the belief, value and responsibility for physical activity via FMS and quality motivation Family invited to engage in the intervention
PERSUASION	Using communication to induce positive or negative feelings or stimulate action	SDT structure for delivery of intervention to develop motivation, self-efficacy, and competence for physical activities. Instructions provided to negotiate challenges as children begin to master skill Variation used to adapt skills that are too challenging at the beginning Feedback on behaviour by inviting children to demonstrate technique, highlight competence to stimulate confidence in skills
TRAINING	Imparting skills	Coaches trained in the fidelity of implementation Non-disruptive in-service training of games-based teaching of FMS. Demonstration of behaviour from the coaches to the teachers, followed by instruction of how to deliver the session. Feedback from coaches Self-monitoring via lesson notes (what went well, what could be improved...) Additional opportunities for practice without supervision FMS development in a games-based mastery approach - use of mastery and constraints to fuel competence and motivation of children
ENABLEMENT	Increasing means/reducing barriers to increase capability or opportunity	Social support (family), Problem solving, Restructuring the environment (social and time) - homework
ENVIRONMENTAL RESTRUCTURING	Changing the physical or social context	Coaches provided with information of how intervention will change how the social context is perceived Restructuring the social comparison to a more mastery/SDT focused approach Children guided towards focus on development of skills via a mastery/SDT approach Once children begin to master technique add challenges (e.g. alternate throwing hand)

To unpack these intervention functions further let us first consider the importance of *the education function* as a way of keeping the child at the centre of the learning whilst also considering all actors (organisms) that have an impact on the learning (e.g., coaches, teachers, parents etc.). According to the TOC, consideration for all organisms around the child maximises efficiency of the intervention in terms of skills acquisition as the emerging behaviour comes from the interplay between all constraints. At this level, the constraints around the organism provide the child with all necessary ingredients to acquire the skills the best way possible in the given context.

Next, *the persuasion function* is utilised to address the child's needs from the content perspective and choice of pedagological approach. Consideration is also given to the environment of the learners so that a motivational climate is fostered and supported. This calls for the teacher taking into account specifics relating to the class, school and social context that surrounds the children.

The training function then, specifically considers the nature of the learning to takes place for all actors of this intervention. Upskilling children is the primary objective, but this can only take place once the organims around the children are themseves equiped with all necessary tools and competency to model and educate them effectively. For these reasons, both coaches and teachers require a training phase as part of the intervention with a view to give confidence and all necessary competence to address the needs of the children.

Similarly, *the enablement function* echoes the training function making specific recommendations in terms of CPD training. Careful consideration is given to the content of the intervention so that we change direction of existing environmental barriers from both a psychological and logistical perspective. In that instance, the TOC and SDT shed some light on the important of a holistic approach in this context demonstrating that all elements around the child are intertwined. This leads us to highlight particularly strong pedagological tools in the CPD that empower coaches and teachers with the skills to differentiate all aspect of the learning process so that it is not "a one size fits all" intervention but an intervention geared towards a personnalised behavioural change. Lastly, *The environmental restructuring function*, indirectly discussed above, is an ideal match with TOC, a crucial philosophy that underpins the intervention. This includes modifying the physical context to alter the task, modifying the environment around the child, and modifying the social context in order promote efficient and long term learning that ultimately, changes the direction of current physical literacy trends associated with Irish children.

To that end, the term ‘refraction’ refers to a change in direction of a wave (e.g. light) as it moves through a medium, realising its true colours and, true potential. In the same way, we propose that the PL design framework outlined in this study could be described as a physical literacy ‘Refraction Framework’, marrying TOC, SDT and mapping functions associated with Behavioural Change Wheel, in order to change the direction of a learner’s movement behaviours, moving them through positive movement experiences in order to realise their true potential. In these *positive movement experiences*, the ‘positive’ component refers to a motivational climate as associated with SDT, the ‘movement’ component relates to TOC and dynamics associated with refined motor coordination outcomes, whilst the ‘experience’ component refers to a multifaceted intervention (the Moving Well-Being Well intervention) where all environmental characteristics around the child are considered. Crucially, a physical literacy refraction framework uses crucial components of physical literacy (specific to Irish learners and the Irish context) as inputs to map design and development of what constitutes an ‘evidence-based’ intervention, which we believe, is best placed to get physical literacy education ‘off the ground’ in Ireland and enable Irish children to ‘reach for the physical literacy stars’ and realise their true potential. The over-arching recipe for the Moving Well-Being Well intervention is outlined in Figure 5.3 below.

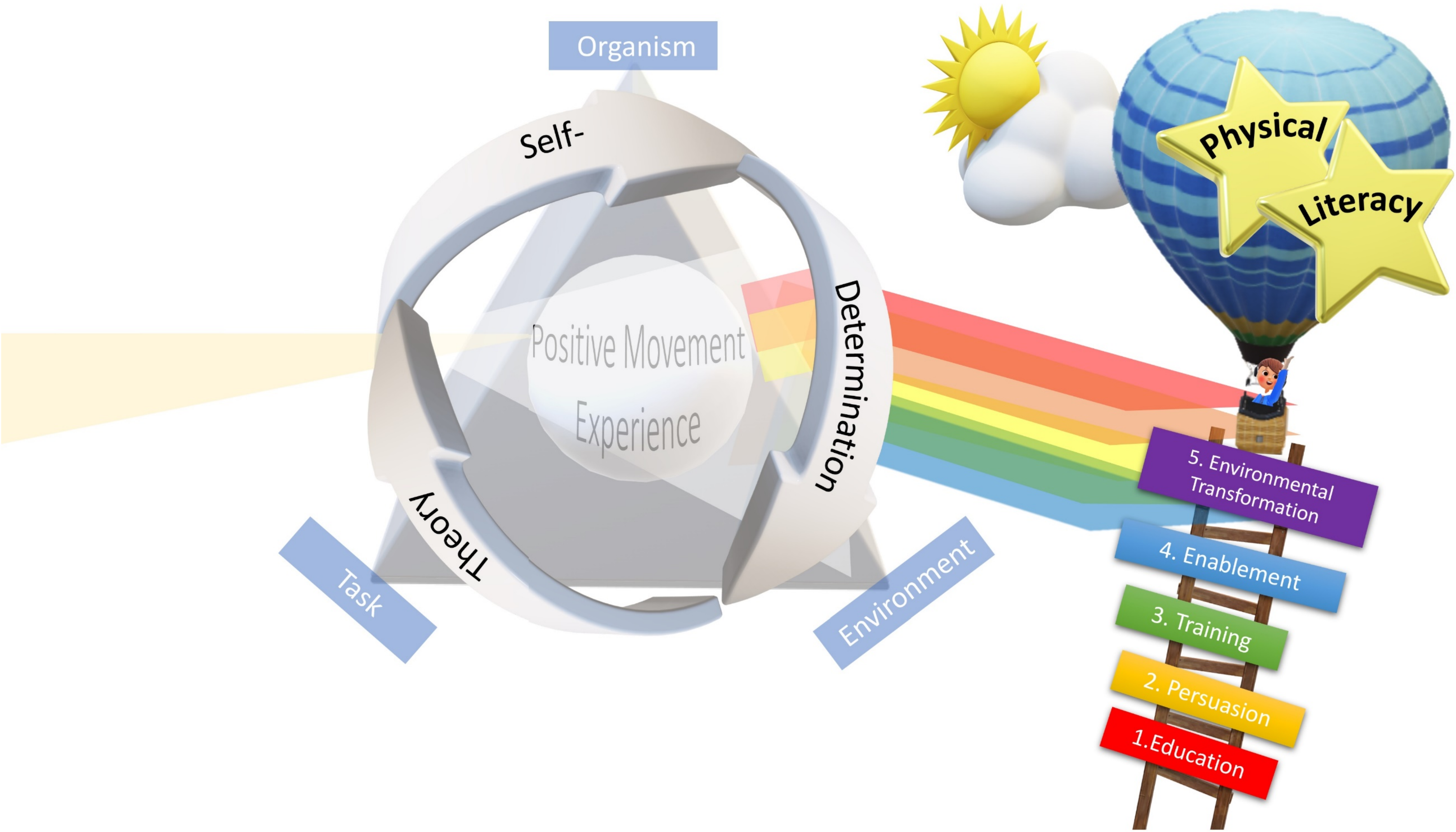


Figure 5.3. Physical Literacy 'Refraction Framework': Seeking to change the nature of movement experiences and the direction of physical literacy outcomes, in Irish school communities

5.5 Moving Well-Being Well in a nutshell and future directions

In the design of this intervention, the existing landscape of PE in Ireland was considered. While there are several resources and initiatives on offer to primary schools, most are sport specific and very few are aligned to the curriculum. One such resource, the Move Well, Move Often programme, seeks to develop physical literacy through FMS and was developed by the Professional Development Services for Teachers Physical Education (PDST-PE). The PDST-PE were approached and agreed to collaborate on this project, which led to the FMS lesson content of the Moving Well-Being Well intervention being made up of extracts from their Move Well, Move Often resource.

As discussed previously, external providers are often used in primary schools to support PE in primary schools. The Moving Well-Being Well project is in partnership with the Gaelic Athletic Association (GAA). The GAA is Ireland's largest sporting organisation and promotes indigenous Gaelic games such as Gaelic football, hurling, camogie, handball and rounders (GAA, 2019). The GAA are the largest external provider in primary schools, providing specialised sport specific support through their community based GAA coaches. Through this partnership, it is envisioned the pilot intervention will be deployed through a network of trained GAA coaches (see Appendices F and G for more details on coach recruitment and training).

The intervention will be delivered to participants in three components: FMS lessons, active classroom activities, and home activities (Stage 3 Step 8). Tailored, 30-minute FMS specific lessons will be delivered by the GAA coach for six weeks. These classes will be delivered in a holistic manner, with a focus on creating a mastery environment. While providing these lessons, the GAA coach will also upskill the teacher in how to deliver an FMS based class. The teacher will have delivered each lesson to their class in the same week before the GAA coach returns to deliver the next lesson. After week six, the teacher must deliver the last two weeks of the intervention without the support of the GAA coach. The intervention aspires to not only improve the FMS levels of the participating children, but also to develop the teacher's ability to deliver an FMS based lesson effectively. In this manner, through the restructuring of the external provision to a more professional development approach, it is hoped to increase the teacher's belief in their own expertise in primary school PE.

Active classrooms have been shown to be an important component to effective, multicomponent interventions in a school setting (Martin & Murtagh, 2015). As part of the Moving Well-Being Well intervention, an interactive whiteboard resource has been designed for each day of the program. These include simple, easy to follow activities for the participants to partake in the classroom for approximately five minutes a day. Through this, the intention is to increase children's PA, develop knowledge and understanding components through the activities, and increase teacher confidence in engaging in active classroom activities.

The final component is the once weekly home activity. The aim is two-fold, to encourage the participants to be active with a parent/guardian and to develop knowledge and understanding.

Throughout the intervention, there will be a focus on just three locomotor skills: hop, skip and jump, and three object control skills: catch, kick and throw. These skills did not all emerge from the national cross-sectional data collection as the weakest, but it is important to note that none are close to mastery (Behan et al., 2109). The designers of the intervention chose these skills for two reason: i) they are easily implementable in any school regardless of amenities available and any equipment required is inexpensive and readily available, ii) these skills, once mastered, will give any individual an excellent foundation to acquire more complex skills used in sport or PA.

Moving Well-Being Well Physical Literacy intervention is an 8 week programme that will be evaluated through a pre-post assessment, with a follow up retention testing after six months. This study was granted ethical approval by the institution Research Ethics committee (DCU/REC/2017/029). Schools will be invited to take part from a selection of primary schools in the targeted study region. Pending a school's recruitment, written consent will be required from school principals, teachers, parents and participants. Participating schools will be matched as best as possible on key demographics including: socioeconomic status, size, ethos and gender. The resulting pairs will make up the intervention and control groups, with each pair having a school in either group. Those schools included in the intervention group will receive the intervention over an eight-week period. All participants will receive baseline testing in week one with follow up assessments in week ten, and retention testing after six months. The primary outcome will be the change in PL components over time.

Overall, the holistic approach to intervention design presented in this study supports the interventionist in targeting a change in PL of Irish children, taking into consideration their motivation and surrounding environmental context. Initial implementation of the intervention will focus on a young cohort so that a preventive medicine approach can be taken to tackle and ‘refract’ existing weaknesses and needs.

Link from Chapter 5 to Chapter 6

Chapter 5 outlines the design and development process of the Moving Well-Being Well (MWBW) intervention. Interventions that are underpinned by relevant theoretical frameworks are those which have proven to be the most successful in achieving their aims (Craig et al., 2008; Kriemler et al., 2011). To that end, the blending of the theory of constraints and self-determinations theory combine to underpin the framework of the MWBW intervention. Those who implement interventions that utilise a multicomponent structure have also been shown to be more successful than those who fail to do so (Craig et al., 2008; Kriemler et al., 2011). The MWBW intervention contains several components, including family, community, active classrooms, teacher training, and external provider components, all of which contain a strong focus on FMS development. With previous chapters outlining the low levels of FMS mastery in Irish children, as well as the purported links between FMS proficiency and future participation in PA (Barnett et al., 2009; Stodden et al., 2008), it seems prudent to intervene.

Chapter 6 aims to measure the effectiveness of the MWBW intervention in increasing FMS proficiency in primary school children in an exploratory trial.

Chapter 6: Exploring the effectiveness of the Moving Well-Being Well intervention on primary school children's motor competence

Manuscript submitted as: Exploring the effectiveness of the Moving Well-Being Well intervention on primary school children's motor competence.

Journal of Motor Behaviour - submitted September 2019, under review

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6.1 Abstract

Multicomponent school based interventions, underpinned by relevant theoretical frameworks, have been shown to be effective in improving fundamental movement skill (FMS) proficiency of primary school children. The aim of this study was to explore the efficacy of one such intervention, the Moving Well-Being Well intervention, in improving FMS levels of primary school children in an exploratory trial. Participants were children aged 7-8 years from ten schools (n = 417, 52% female, mean age 7.6 ± 0.66 years). Intervention schools (n = 5) received the Moving Well-Being Well eight week intervention, with the remaining schools continuing with usual care. FMS were measured using the TGMD-3, with an additional vertical jump and balance assessment included. BMI was also recorded. Assessments took place at baseline, post-intervention and at six month retention. Multilevel analyses were performed using SPSS. Significant interaction effects across time were observed for FMS ($p < 0.001$). The effects of the intervention were significant for the intervention group regardless of gender, school or BMI status. The Moving Well-Being Well intervention has the potential to improve FMS proficiency of primary school children.

Keywords: Fundamental movement skills; school based intervention; multicomponent intervention, physical literacy; physical activity.

6.2 Introduction

Fundamental movement skills (FMS) are the building blocks of more advanced, complex movements that are required to take part in sport, or context specific physical activity (PA) (Logan et al., 2018). There are three subtests of FMS: locomotor skills (e.g. run, jump, skip), object control skills (e.g. kick, throw, catch), and stability skills (e.g. balance) (Gallahue & Ozmun, 2006). These basic skills can be mastered by the age of six (Gallahue & Ozmun, 2006), and all children should have acquired mastery level by age ten (Hardy et al., 2010). Once mastered, children can refine and combine these skills, allowing for the acquisition of more complex sports specific movement skills (Metcalfe & Clark, 2002). An increase in children's FMS proficiency is purported to positively impact PA participation in later life (Barnett et al., 2009; Lubans et al., 2010; Okely et al., 2001). Several studies examining the relationship between FMS and PA in children and adolescents have found positive correlations (Barnett et al., 2015; Fisher et al., 2005; Hardy et al., 2013), and suggested that a focus on FMS development in children is a key driver towards increased PA participation of adolescents (Barnett et al., 2009; Jaakkola et al., 2016; Stodden et al., 2008). It is has been reported that if an individual lacks proficiency in performing FMS, they will be less likely to take part in PA (Barnett et al., 2016; McGrane et al., 2017). Any increase in sedentary behaviour can lead to negative health implications, such as increased risk of heart disease and increased adiposity (O'Brien et al., 2016; Pate et al., 2006). Throughout the key childhood years, it seems imperative to focus on the development of correlates of PA such as FMS.

Numerous studies make the assertion that these FMS must be taught (Clark, 2007; Haywood & Getchell, 2019) and practiced both in free-play and a school setting (Booth et al., 1999; Mitchell et al., 2013; Okely et al., 2004). The primary school environment is proposed as a key setting to develop FMS, particularly during the physical education (PE) lessons (McKenzie & Lounsbery, 2009). Okely and Booth (2004) maintain that FMS should be included in any primary school PE curriculum. The Irish primary school PE curriculum purports to have a focus on FMS, "*stressing personal and social development, physical growth and motor development*" (Department of Education and Skills, 1999, p.6). Recent findings have reported low levels of FMS mastery throughout the Irish primary school cohort (Behan et al., 2019), with other Irish studies producing similar findings (Kelly et al., 2018; Farmer et al., 2017; Bolger et al., 2018). Furthermore, research examining FMS in Irish adolescents also found low levels of mastery

(O’Brien et al., 2016), which is alarming as most would have undergone eight years of primary PE. While a focus on motor development may be present in the curriculum, the empirical evidence suggests that more needs to be done. The school setting has been singled out as a key stage to intervene and increase FMS proficiency (Belton et al., 2014; Khambalia et al., 2012; O’Brien et al., 2013; Salmon et al., 2007). Schools provide a particularly salient opportunity for interventions that target FMS development (McKenzie & Lounsbery, 2014; McKenzie & Lounsbery, 2014b), with PE lessons providing ample opportunity to intervene (McKenzie et al., 2009). The low levels of FMS presented by Behan and colleagues (2019) may be due to the fact that there are no specialised PE teacher at primary level in Ireland. A lack of FMS proficiency can lead to less participation in sport or PA (Barnett et al., 2009; Jaakkola et al., 2019). Females are said to be particularly affected to this due to the widely reported fact that their male counterparts tend to have significantly higher FMS, specifically object control skills (Bardid et al., 2016; Barnett et al., 2010; Kelly et al., 2018; Okely & Booth, 2004; van Beurden et al., 2002). Given the poor levels of FMS mastery presented, it is crucial that interventions targeting FMS in primary school children are developed, as it may have a positive effect on children’s PA participation (Cliff et al., 2009).

Interventions targeting FMS in the school setting have been shown to be effective in numerous studies (Lai et al., 2014; Logan et al., 2012; Lubans et al., 2010). The SPARK programme (n = 745, mean age 9.25 years) was successful in significantly increasing FMS through PE lessons (McKenzie et al., 2009). The ‘Move it Groove it’ programme (n = 1045, age range 7 – 10 years) produced significant improvements in FMS proficiency in Australian children, and is a multicomponent intervention including teacher training, parents and resources for parents and teachers (van Beurden et al., 2003). In Ireland, the Youth Physical Activity Towards Health (Y-PATH) is an effective, multicomponent intervention which has reported significant increases in FMS in adolescents (McGrane et al., 2018). Delivered in second-level schools by specialist PE teachers (n = 482, age range 12 - 13 years), it comprises of four strands: the student, the teacher, the family, and a multi-media component (McGrane et al., 2018). One of the few FMS interventions in Irish primary schools, ‘Project Spraoi’, found significant improvements in FMS over the academic year (n = 357, age range 6 - 10 years) (Bolger et al., 2019). While this study is also multicomponent, it is not without its limitations, as the researchers admit the control and intervention schools were unmatched in terms of sex and geographical location (Bolger et al., 2019). It is evident that multicomponent interventions targeting FMS are the most effective, although there are other important considerations.

Reviews of school based interventions provide evidence that the more effective strategies involve multiple components and are not limited to PE lessons (Kriemler et al., 2011; Murillo Pardo et al., 2013; Salmon et al., 2007; Tiemperio et al., 2004). For instance, there is substantial evidence supporting the inclusion of a community component, with findings suggesting that community organisations have the capability to facilitate activities that the students may find attractive in the school setting (Acker et al., 2011). Interventions which target a family involvement have shown positive effects on increased PA participation (Belton et al., 2014; De Meij et al., 2010; Murillo Pardo et al., 2013). Active classrooms are another intervention component that have emerged in recent research, and have been proven effective in increasing PA across the school day (Goh et al., 2014; Martin & Murtagh, 2015). Previous research around FMS interventions have shown the benefits of a teacher development component, with trained teachers achieving significantly greater results than their untrained counterparts (McKenzie et al., 2009). Others have shown the positive impact that an external provider can have on participant FMS proficiency (Rush et al., 2016). The most effective strategies targeting improvements in FMS appear to include a multicomponent intervention in the school setting, although when designing such an intervention it is important to also follow a relevant theoretical framework.

Following a specific and relevant theoretical framework (Craig et al., 2008) allows for the intervention to be effectively evaluated, and also highlights ways in which the intervention can be improved (Michie & Abraham, 2004). According to the National Institute for Health and Care Excellence (NICE), behavioural change results from an interaction of an individual’s capability, opportunity, and motivation to perform and carry out said behaviour (NICE, 2014). This is known as the Capability-Opportunity-Motivation Behaviour (COM-B) model, and Michie and colleagues (2011) maintain that change must take place in one or more of these components for significant behaviour change. Michie et al. (2011) have synthesised all 19 frameworks into the Behavioural Change Wheel (BCW). The BCW has the COM-B model at its core and provides an evidence-based approach in developing interventions aimed at changing behaviours to suits the designer’s needs (Michie et al., 2014). Interventions implementing the BCW have produced positive results in changing the targeted behaviour, with examples in healthcare (Bonner et al., 2013), mental health services (Crowther et al., 2013), and the school setting (Martin & Murtagh, 2015). Similar to these effective interventions, the MWBW program is underpinned by both the constraints theory and self-determination theory, designed using the framework outlined by the BCW (Issartel et al., 2019, *under review*).

As outlined in the previous chapter (Issartel et al., 2019, *under review*), the MWBW program is designed as a multicomponent intervention that emphasises FMS development, and includes family, community, active classroom, teacher training, and external provider components. There is an increasing trend in Ireland towards the use of external providers in the primary school PE setting (Murphy et al., 2012), and the MWBW intervention seeks to capitalise on the largest external providers in the form of upskilling and intervention deployment. The aim of this study was to evaluate the efficacy of the MWBW intervention in improving FMS proficiency in primary school children.

6.3 Methodology

Design and Participants

The intervention was an eight-week exploratory trial examining the effect of the 'Moving Well-Being Well' programme on children's FMS proficiency. Twelve primary schools in the Dublin region were approached, with ten agreeing to take part in the study. The schools were matched based on similarities in school size (small: 0 - 199, medium: 200 – 399, large: 400+), gender (female only, male only, mixed gender), and the socioeconomic status designated to the school (disadvantaged or non-disadvantaged). One school from each pairing was randomly selected to be part of the intervention group and the others were allocated to the control group. After initial consent was obtained from the principals in each participating school, parental consent and participant assent were obtained.

The intervention was aimed at seven and eight-year-old children, no exclusion criteria, in first and second class of primary school. Due to the young age of the participants (n = 417, 52% female, mean age 7.6 ± 0.66 years), an age appropriate assent form was developed and supplied to participants. Age and sex were collected through both consent forms and questionnaires administered in class. To ensure anonymity, a unique ID was produced for each participant. Data were collected March through November 2018. Ethical approval was obtained from the institutional Research Ethics Committee (DCU/REC/2017/029). Students only experience of PE was through a non-specialist primary school teacher.

Intervention

The Moving Well-Being Well intervention is an eight week FMS development programme implemented by both specialised sports coaches (community based professional Gaelic Athletic Association coaches) and primary school teachers. Note that the Gaelic Athletic Association (GAA) is Ireland's largest sporting organisation and promotes indigenous Gaelic games such as Gaelic football, hurling, camogie, handball and rounders (see Appendices F and G for more details on coach recruitment and training).. The MWBW intervention provides professional development for primary school teachers in the school setting. The intervention contains structured, twice weekly 30-minute FMS development lessons for the participating students. The first lesson was led by the GAA coach accompanied by the teacher and the second lesson took place in the same week delivered exclusively by the teacher, alongside daily classroom activities, and weekly home activities (Issartel et al., 2019, *under review*). The control group continued with their usual PE program (see Appendix E for more details on curriculum) and did not receive any specialised sports coaching for the duration of the study. Further detail on the MWBW intervention development and structure is shown in Chapter 5 (Issartel et al., 2019, *under review*). The intervention is a multicomponent, primary school intervention incorporating the following components: 1) The student: specific focus on developing FMS proficiency, 2) The GAA coach component: coach undergoes training in administering the intervention to develop FMS, and also upskill the teacher (Training and recruitment outlined in Appendix F & G), 3) The teacher: all teachers will receive on the job upskilling in how to develop FMS in the school environment, 4) Active classroom component: interactive whiteboard resources are provided for five minute active breaks in the classroom, 5) Parental component: home activity resources are made available to encourage parents to be active with their children and develop their FMS.

Measures

Participants FMS proficiency was primarily assessed through the Test of Gross Motor Development-3rd Edition (TGMD-3). The TGMD-3 is comprised of locomotor (run, skip, gallop, slide, hop, and horizontal jump) and object-control (catch, overhand throw, underhand roll, kick, two handed strike, one handed strike, and stationary dribble) skill subtests (Ulrich, 2013). Also included was an additional locomotor skill test, the vertical jump, from the Victorian Fundamental Motor Skills manual (Department of Education Victoria, 1996, *Fundamental Motor Skills: A Manual for Classroom Teachers*, Melbourne: Education Department of Victoria), and the balance subtest from the Bruininks-Oseretsky Test of Motor Proficiency 2 (BOT-2) Short Form (Bruininks, 2005). All measures have established validity (Temple & Foley, 2017) and reliability in this age cohort (Cools et al., 2009; Yee et al., 2010), with the combined locomotor, object control and balance subtests in this study giving good internal consistency reliability ($\alpha = 0.80$). All members of the research team underwent formal training in both the assessment protocols and grading to ensure consistency in assessment. The lead researcher pre-coded a sample data set and the research team, who were blind to the coding conditions, met 95% inter-rater agreement on this data set.

Body composition was measured using body mass index (BMI). Height and mass was measured using a stadiometer and a scale in accordance with standardised procedures

(Meredith & Welk, 2010). Height was measured to the nearest 0.1cm and mass to the nearest 0.5kg, which allowed BMI to be calculated (BMI= weight (kg)/height (m^2)). Appropriate care was taken to the sensitivities of testing BMI.

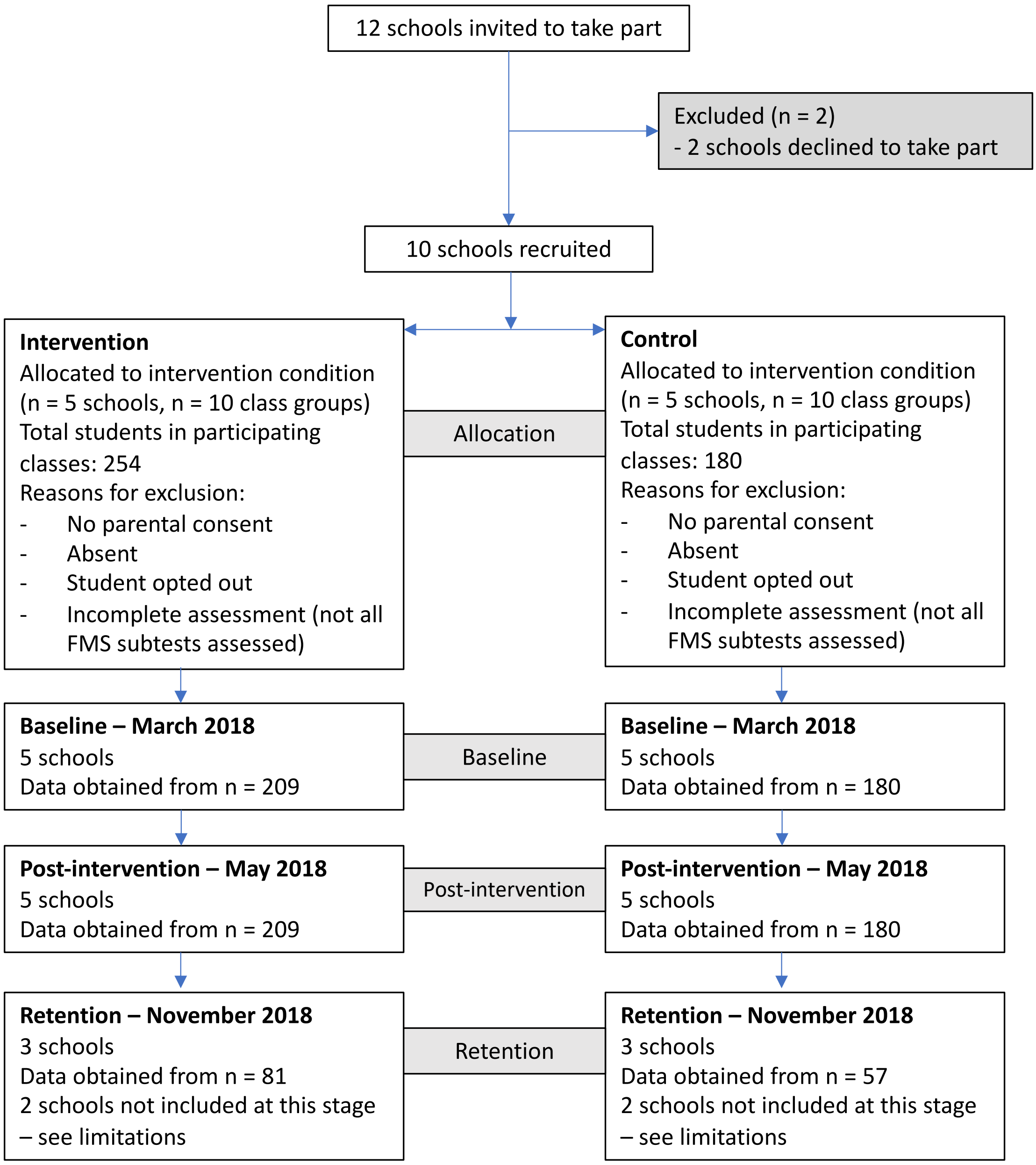

Figure 6.1 Flow chart of participants through the study

Data Collection

FMS data were collected at three time points: baseline measures at the beginning of the intervention (March 2018), eight weeks later post intervention (May 2018), and retention tests six months post intervention (November 2018). As per the protocols outlined with the assessment tools, a trained research team member provided a visual demonstration of each skill (Ulrich, 2013; Bruininks, 2005). Participants were given no verbal cues or feedback and were not made aware of the criteria required to be successful in each skill assessment. After performing a familiarisation trial of each skill, the participants had to perform all skills twice. A trained member of the research team observed both trials and assessed each skill criteria. Consistent with protocols, a score of '1' was awarded if criteria were met and a score of "0" was awarded if the participant failed to fulfil the criteria. Scores from both trials were summed to give a total score for each skill. The balance assessment awarded points based on the outcome of the performance of each skill, ranging from zero to four (Bruininks, 2005). Locomotor, object control, and balance scores were totalled to give subtest scores and combined to give an overall FMS score. While traditionally, these measures are collected using a pen and paper method, an innovative iPad application was developed to collect the data used in this study, full details described in Behan et al. (2019). All protocols as outlined in the research were adhered to during data collection (Ulrich, 2013; Meredith & Welk, 2010). Upon completion, data were uploaded to a secure server based on the university campus. The app is fully compliant with the general data protection guidelines (GDPR) dictated by European law, and was approved by the institutions ethics committee.

Data Analysis

All analyses were performed using SPSS software version 24 (IBM Corporation). Multilevel linear regression analysis was used to examine the effect of the MWBW intervention on FMS. A three level multilevel structure was proposed with random intercepts, where time (Level one), children (Level two) and schools (Level three) served as the grouping variables; time was treated as a fixed effect in the model but was also incorporated as a random slope effect (repeated measure) in the residual component. All fixed effect interactions were examined. The repeated measures component was analysed for identity, unstructured, unstructured heterogeneous, autoregressive, autoregressive heterogeneous and compound symmetry variance structures. Multilevel models have the ability to handle models with varying time points. This is advantageous over the traditionally used repeated-measures ANOVA, where usually the entire case is removed if one of the outcomes is missing. Multilevel models do not assume an equal number of occasions or fixed time points, so all cases can be used for analysis.

Regression coefficients for the group variables (where ‘0’ indicated Control schools, and ‘1’ indicated Intervention schools) reflected average differences in the outcome variable over time adjusted for baseline outcome values, timing of follow-up measures, and a priori covariates known to moderate FMS (gender and BMI) over three time periods. To determine the time points at which any intervention effects occurred at baseline (Time 1), post-intervention (Time 2) and retention timepoints (Time 3), post-hoc stratified analyses comparing the estimated marginal means of the interaction variables were performed for the Intervention and Control groups, and comparisons were made with t-tests using Satterwhaite degrees of freedom. Random Intercepts were assessed for significance using the Wald statistic with statistical significance set at $p<0.05$. The covariance structure of the mixed model was evaluated by assessing the Akaike information criterion (AIC) and Bayesian information criterion (BIC).

6.4 Results

From the ten participating schools a total of 389 participants were recruited. Participant retention ranged from 100% at post-intervention to 31.7% at retention in the control group. The intervention group's retention ranged from 100% at post-intervention to 42.6% at retention follow up (Table 6.2). Participation levels were reduced significantly at the retention follow up as only a subsample of the original participants was tested due to logistical issues. FMS levels of intervention and control groups across the three time points are given in Table 6.2, and shown graphically by gender and intervention condition in Figure 6.2.

Table 6.1. Means (±SD) of FMS components at baseline, post-intervention and retention timepoints.

Intervention Group	n	Baseline	n	Post-Intervention	n	Retention
Locomotor	246	41.66 (6.98)	246	39.58 (4.68)	103	45.41 (3.88)
Object Control	238	27.94 (10.09)	238	40.22 (7.65)	116	39.89 (6.76)
Balance	237	5.14 (2.04)	237	6.28 (1.91)	115	6.58 (1.72)
Control Group						
Locomotor	201	42.70 (6.31)	201	35.15 (4.99)	73	43.38 (5.08)
Object Control	195	30.06 (9.16)	195	31.15 (10.15)	83	32.63 (9.34)
Balance	237	5.22 (2.03)	235	5.54 (2.09)	74	6.28 (1.41)

Table 6.2. Means (±SD) of overall FMS, at baseline, post-intervention and retention timepoints.

Group	n	Baseline	n	Post-Intervention	n	Retention
Intervention Male	88	76.65 (15.58)	88	88.34 (11.08)	37	92.84 (8.32)
Intervention Female	121	72.82 (12.87)	121	84.82 (10.15)	44	91.25 (8.67)
Intervention Overall	209	74.43 (14.17)	209	86.36 (10.70)	81	91.98 (8.50)
Control Male	91	81.21 (13.37)	91	79.85 (11.86)	27	88.32 (12.87)
Control Female	89	74.06 (11.57)	89	71.27 (12.63)	30	76.97 (12.01)
Control Overall	180	77.67 (12.98)	180	75.47 (12.96)	57	81.93 (13.35)

An Identity (ID) covariance structure was found to have the lowest AIC and BIC. The random intercept for School was found to be non-significant (3.593, $p = 0.090$, Wald $Z = 1.697$), but the ID repeated measures (39.020, $p < 0.001$, Wald $Z = 18.676$) of the error term was found to be significant. In this model the intercept term at a school level was excluded, as between-school variation was not significantly determining FMS variance. Baseline BMI and the interaction between baseline BMI and intervention, were also found to be insignificant.

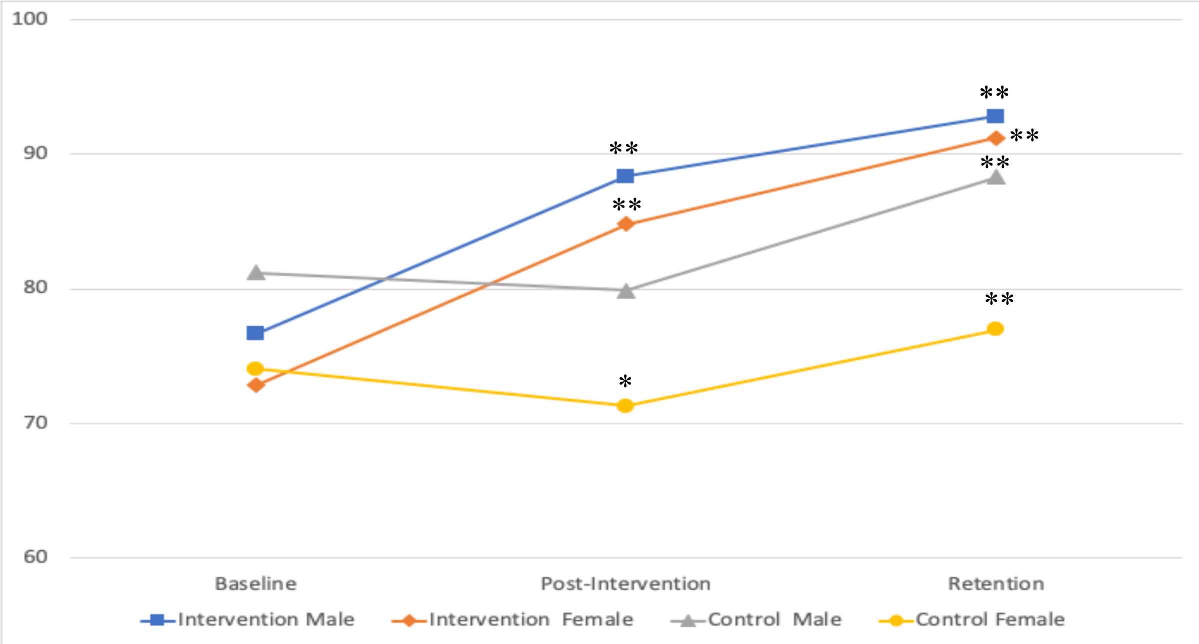

*Figure 6.2. Overall FMS proficiency for intervention and control groups at baseline, post-intervention and retention timepoints (Max score of 120). Significant differences from baseline to post-intervention and baseline to retention depicted as p < 0.01 = *, p < 0.001 = **.*

The final parameter estimates for the main fixed effects of the final model choice are shown in Table 6.4, and similarly the Type III test effects for the final interaction effects are shown in Table 6.3.

Table 6.3. Type III analysis of interaction effects

Parameter	F	df	p
Time*Group	124.622	(2, 681.971)	0.000**
Gender*Group	2.341	(1, 700.018)	0.119
Gender*Time	0.974	(2, 701.945)	0.378
Gender*Group*Time	3.138	(2, 701.945)	0.044*
Baseline FMS*Group	11.612	(1, 703.076)	0.001**

Table 6.4. Parameter estimates of main fixed effects

Parameter	Estimate	S.E.	df	t	p	C.I.
Intercept	35.257	2.298	283.101	15.343	0.000**	(30.733, 39.780)
Time						
Time (1v2)	-14.5005	1.459	704.399	-9.943	0.000**	(-17.379,-11.641)
Time (1v3)	-0.987	1.49	703.655	-0.662	0.508	(-3.912, 1.939)
Gender (M/F)	0.751	1.607	698.856	0.467	0.64	(-2.405, 3.907)
Group	-17.648	3.689	345.618	-4.784	0.000**	(-24.903,-10.393)
Gender*Group	-6.233	2.637	701.312	-2.363	0.018*	(-11.410,-1.055)
Time*Gender						
Time 1*Gender	-1.325	1.886	702.805	-0.703	0.482	(-5.028,2.378)
Time 3*Gender	-3.698	1.921	701.366	-1.925	0.055	(-7.469,0.073)
Time*Group						
Time 1*Group	9.686	2.126	705.991	4.371	0.000**	(5.335, 14.036)
Time 3*Group	-7.048	2.256	705.955	-3.125	0.002**	(-11.476,-2.620)
Gender*Group*Time						
Time 1*Gender*Group	5.474	3.007	705.638	1.82	0.069	(-0.430,11.379)
Time 3*Gender*Group	7.625	3.052	705.783	2.499	0.013*	(1.633, 13.617)
Baseline FMS	0.723	0.023	705.991	4.371	0.000**	(0.678, 0.767)
Group*Baseline FMS	0.122	0.036	703.076	3.4008	0.001**	(0.052, 0.192)

Post hoc analysis on the group comparisons of the intervention interaction with time are outlined in Table 6.5.

Table 6.5. Post hoc contrast test analysis for significant interaction effects.

Comparison	Estimated Difference	d	p	C.I.
Baseline Control vs Baseline Intervention	-8.341	0.238	0.007	(-14.367, -2.316)
Retention Control vs Retention Intervention	20.764	0.898	0.000**	(-27.294, -14.235)
Baseline Control vs Retention Control	2.745	0.324	0.024*	(-5.123, -0.367)
Baseline Intervention vs Retention Intervention	15.168	1.502	0.000**	(-17.073, -13.262)
Retention Female Control vs Retention Female Intervention	17.648	1.363	0.000**	(24.903, -10.393)
Retention Male Control vs Retention Male Intervention	23.303	0.417	0.000**	(-29.295, -17.312)

6.5 Discussion

The main aim of this study was to evaluate the efficacy of the MWBW intervention in improving primary school children's FMS proficiency. Overall, the results support a significant positive intervention effect for FMS proficiency.

The baseline results presented in Table 1 indicate that FMS levels in this sample were below the expected proficiency for this age group. Participants were aged seven to eight years old (mean age = 7.6 ± 0.66 years) and as such should be capable of demonstrating mastery in the basic FMS (Gallahue & Ozmun, 2006). While Logan and colleague (2010) suggest that all FMS should be mastered by ten years of age, it could be expected that some of the participants involved in this research would be at least approaching FMS mastery. The baseline measures, however, for both intervention (74.43) and control groups (77.67) are well short of the maximum 120 points achievable. The findings presented here confirm the low FMS proficiency levels that have been reported elsewhere, both nationally (Behan et al., 2019; Kelly et al., 2018) and internationally (Lubans et al., 2010; Mukherjee et al., 2017), highlighting the need for interventions such as the MWBW program to tackle low FMS proficiency levels. Considering that these FMS are the building blocks to more complex, sport specific skills, and potentially predict future PA engagement (Barnett et al., 2009; Jaakkola et al., 2019; Stodden et al., 2008), it is important that children of a primary school going age receive the opportunity to build a strong foundation in these skills.

Significant interaction effects observed over time highlight the effectiveness of the intervention ($p < 0.001$). Post hoc results from the multilevel analysis show the intervention group significantly increases FMS proficiency from baseline (74.43) to retention (91.98) in overall FMS ($p < 0.001$, $d = 1.502$). The fact that the positive results were retained six months later is notable, as there is limited research which report retention testing of FMS (Zask et al., 2012). The results also show the mean FMS score increases from post-intervention (86.36) to retention (91.98) in the intervention group. While this suggests that the MWBW program continued to have an effect on the participants FMS after the intervention had concluded, this finding must be taken with caution as this could be explained through maturation. A possible reason for this may be the inclusion of the teacher training component (Chapter 5; Issartel et al., 2019, *under review*), as the teachers were upskilled in teaching FMS throughout the program and may have continued to focus on FMS development in their regular PE classes after the intervention had finished. The control group, however had significantly higher FMS levels at baseline than the intervention group (p = 0.007, d = 0.238). Even with these baseline characteristics, the control group also showed a significant improvement (p = 0.024, d = 0.324) in overall FMS from baseline (77.67) to retention (81.93). This element is important to highlight, as it shows the impact of growth and maturation on children's motor development, and is similar to trends reported in previous work (Behan et al., 2019). Intervention simply fosters and accelerates the learning curve. The intervention group experienced a larger degree of change as shown from the difference in effect size and the actual mean differences over time. This highlights the effectiveness the MWBW intervention.

This study highlights that that the MWBW intervention is effective in improving both male and female FMS proficiency (see Figure 6.2). There were no significant interaction effects between gender*intervention (p = 0.119), or gender*time (p = 0.378), however there was a significant interaction effect between gender*intervention*time (p = 0.044). This result tells us that while the intervention increases both boys and girls FMS proficiency (see Figure 6.2), it also affects boys and girls differently across the course of the intervention. Males and females do not typically develop FMS at the same rate, with males frequently reported as superior in object control skills compared to their female counterparts (Bardid et al., 2016; Barnett et al., 2010; Kelly et al., 2018; Okely & Booth, 2004; van Beurden et al., 2002). Low levels of FMS proficiency in females may contribute to increased physical inactivity (Hardy et al., 2013). The MWBW intervention is a potential vehicle to target females with poor levels of FMS proficiency, and potentially increase PA levels. Any decrease in PA participation could lead to negative health outcomes such as increased adiposity (Pate et al., 2006). There is an increasing prevalence in overweight or obese children worldwide (Ogden et al., 2006), and this is having a negative effect on PA levels. Any increase in mass or decrease in PA can also have negative consequences for FMS development (Ogden et al., 2006), which can in turn hamper involvement in sport or PA in which these basic skills are required (Metcalfe & Clark, 2002). These findings highlight the importance of interventions that target the development of FMS, such as the MWBW program, that may have the knock effect of increasing future PA participation.

In line with previous studies, the findings presented here show that FMS can be improved with the correct teaching techniques and pedagogical tools (Lubans et al., 2010; Clark et al., 2007). McKenzie and colleagues (2009) suggest that trained teachers can elicit significantly greater improvements in FMS than their untrained counterparts. Research has shown that primary school teachers feel inadequately prepared to teach PE effectively, and all strategies that seek to improve teachers competence in delivering PE should be considered (Fletcher & Mandingo, 2012). The multicomponent nature of the MWBW intervention is structured to address this, with a teacher training component included. The results presented in this paper show significant improvements in the intervention group after the intervention was completed. Teachers may have gained confidence in delivering FMS based lessons through their training over the intervention period, as previous studies have shown similar approaches have increased teacher confidence in delivering PE (Lander et al., 2015). Providing generalist primary school teachers specialised training to equip them with the confidence and skills to promote FMS in schools may well be an important strategy to help address the existing youth FMS deficiency. Ireland has seen an upsurge towards the use of external providers in the primary school PE landscape (Murphy et al., 2012), with the GAA being one of the largest providers. A recent study has recommended increased communication and involvement with external providers in Ireland, in an effort to change the existing dynamic in which the teacher views the external provider as the expert (Ni Chroinin & O'Brien, 2019). The MWBW program seeks act on these recommendations and, though its partnership with the GAA, utilise the existing infrastructure of community based coaches, potentially providing a new avenue of professional development in primary school PE.

The results of this exploratory trial of the MWBW program provides further evidence supporting the use of multi-component school-based interventions to improve FMS levels of primary school children. While the MWBW intervention has been proven to be effective in this study, a larger randomised controlled trial is the logical next step in order to ascertain its efficacy and scalability to a wider cohort of children.

Strengths and Limitations

A strength of the study was the use of the multilevel analysis which took into account the nested nature of the data. One limitation was the sample size at retention stage was not as high as desired. This was due to the fact that two schools who participated in the study are classed as junior schools. This means that they only cater for five to seven year olds (junior infants to first class in an Irish primary school context). Upon completion of junior school, the participating students involved in the study were dispersed to several different schools, and as such, the logistics of reassessment at this stage were unfeasible. The use of the multilevel analysis model does account for this, but it is a limitation nonetheless. While the results presented show significant increases in FMS proficiency in the interventions group, we cannot say which component of the intervention had the most impact. Future studies must look at measuring the efficacy of each component of the intervention on participant's FMS. Lastly, in order to ensure the intervention was delivered as prescribed, the GAA coaches received in-service training (details in Appendix F & G) , resources, and were under instruction to contact two of the lead researchers at any stage if assistance was required. There was, however, limited data on the fidelity of implementation collected during the course of the study. Any future research involving the Moving Well-Being Well intervention must measure the fidelity of how both the intervention protocols were adhered to by the teachers, parents, and the coaches, as well as rigorously documenting the PE activities undertaken by the control groups.

Conclusion

This study highlights the lack of FMS proficiency in primary school children, with participants mirroring similar poor levels previously reported in Irish research (Behan et al., 2109; Kelly et al., 2018). As FMS proficiency is so closely linked with future PA participation (Lubans et al., 2010), it is imperative that FMS development be made a priority in primary schools. This study shows the impact that both a professional coach and a trained teacher working together can have on improving FMS proficiency. This intervention offers a potential avenue towards solving the problem of low FMS levels among children. This study highlights the effectiveness of a multi-component school-based intervention on FMS proficiency among primary school aged children.

Chapter 7: Conclusions and Future Directions for Moving Well-Being Well

7.1 Overview of Thesis

Physical literacy (PL) is a complex, multi-faceted construct and is commonly defined as "*the motivation, confidence, physical competence, knowledge and understanding to be physically active for life*" (IPLA, 2015). PL purported to be a key driver of children's physical activity (PA). As the health benefits associated with PA have been widely discussed in this thesis, every effort to understand factors relating to the worldwide trend of declining PA levels should be undertaken (Beals et al., 2016; Bryant et al., 2014; Hills et al., 2011; Woods et al., 2018). PL may be able to help us understand why children choose to be physically active (or not) (Tremblay, Costas-Bradstreet et al., 2018), but in order for this to happen, each component must be examined in more detail. This thesis investigated the physical competence component of PL. The physical competence component is made up of an individual's health related fitness characteristics and also their basic motor skill proficiency (Logan et al., 2018; Tremblay et al., 2018), which are commonly referred to as the fundamental movement skills (FMS).

There is a trend reporting low levels of FMS throughout the world (Barnett et al., 2009; Lubans et al., 2010; Mukherjee et al., 2017). Given the substantial evidence linking FMS with future PA participation (Barnett et al., 2009; Stodden et al., 2008; Jaakkola et al., 2019), and the associated health benefits (Pate et al., 2012), it seems clear that efforts to increase children's FMS proficiency should be explored. There is, however, first a need to establish baseline measures in order to measure progress. There have been several studies done in Ireland examining FMS in children (Bolger et al., 2018; Farmer et al., 2017; Kelly et al., 2018); all are limited due to the relatively small and local samples used. While the findings from these studies are important indicators of where Irish children's FMS proficiency may lie, no definitive conclusions can be drawn due to the aforementioned limitations. This presented a clear need for a large scale, representative sample to ascertain the levels of FMS proficiency in Irish primary school going children. This was the main objective of the study outlined in chapter 3, with a large sample size of over 2,000 children from 100 different classes in 44 schools across 12 counties. The national sample incorporated the entire primary school cohort, from five to twelve years of age. This study was designed in such a way to reflect the primary school landscape in Ireland, taking socioeconomic status, geography, gender and school ethos into account. The cross-sectional data gives a true reflection of Irish primary school children's FMS status.

Chapter 3 highlighted the lack of FMS proficiency throughout Irish primary school children. The findings show children demonstrate low levels of mastery, or near mastery (MNM) of locomotor, object control and balance skills. The literature tells us that FMS mastery could occur as early as six years old (Gallahue & Ozmun, 2006), and all skills should be mastered by ten years of age (Hardy et al., 2010), so one would expect children towards the end of their primary school journey to be at least approaching FMS mastery. This is not the case, however with the results showing that skills plateau at ten years of age, despite the fact that FMS mastery status has not been attained. Boys and girls do not develop FMS at the same rate, with research consistently reporting males recording significantly higher scores in the object control skills than their female counterparts (Bardid et al., 2016; Barnett et al., 2010; Kelly et al., 2018; Okely & Booth, 2004; van Beurden et al., 2002). The findings in chapter 3 reinforce such findings, with Irish boys showing significantly better results in object control skills across the entire span of primary school. Much is made of sport and PA 'drop-out', but it stands to reason that if children have not mastered the FMS, it is unlikely they will acquire the more complex skills to facilitate participation in sport or PA (Barnett et al., 2010). The result will be children shying away from PA. The negative health implications associated with physical inactivity have been extensively discussed in this thesis, as has the relationship between FMS proficiency and PA. Stodden and colleagues (2008) maintain that this relationship is part of a wider conceptual model producing either positive or negative trajectories towards health. Others have demonstrated indirect pathways from motor competence to engagement in PA through HRF (Jaakkola et al., 2019). It seems logical that any relationships with FMS that relate to PA, such as HRF, should be investigated further. Chapter 4 attempted to do this through the examination of the relationship between FMS and HRF across Irish primary school children.

The relationship between FMS and HRF is widely researched and there is substantial evidence supporting a positive relationship (Cattuzzo, et al., 2016). Many, however only use a component of HRF as a proxy in their studies, and this may not give a true reflection of the relationship. Stodden and colleagues (2014) used a composite score made up of several HRF components to examine the relationship with FMS, and they propose that the relationship is dynamic and strengthens with age. Again, this suggestion has limitations, as the researchers only used a very small range of FMS skills (Stodden et al., 2014). In the study outlined in chapter 4, the authors identified the gap in the literature and examined the relationship of the full FMS spectrum against each of the HRF components across the entire primary school age cohort. The results predominantly backed up the assertions made by Stodden et al. (2014), and showed the relationship between FMS and HRF is dynamic and strengthens with age, with the FMS subtests contributing to the various HRF components in different ways. The results suggest that improving children's locomotor and balance skills could improve body composition, and that increases in object control proficiency could lead to increase in muscular strength. The findings also show that developing overall FMS could lead to increases in muscular endurance and cardiovascular endurance as children get older. The positive health benefits linked with these HRF components are well established (Ortega et al., 2008), so it is logical to seek to increase HRF in children to promote a healthier lifestyle. While this study is cross-sectional in nature and cannot confirm causal pathways, it seems that the relationship between FMS and HRF may be reciprocal, due to the fact that by their very nature, activities which improve HRF involve movement, which in turn may improve FMS (Stodden et al., 2014). A theme throughout this thesis has been the link between FMS and increased PA participation (Barnett et al., 2009; Stodden et al., 2008; Jaakkola et al., 2019), and with research in Ireland showing a trend of poor HRF and FMS proficiency levels in both children and adolescents (Belton et al., 2014; Bolger et al., 2018; Kelly et al., 2018; O' Brien et al., 2016), the need to promote FMS development seems clear to promote positive health outcomes in children and adolescents.

The school setting has been suggested as particularly suitable environment in which to develop FMS (Khambalia et al., 2012; O' Brien et al., 2013; Salmon et al., 2007). In particular, physical education (PE) lessons provide an ideal opportunity to promote FMS (McKenzie & Lounsbery, 2009). Recent Irish research has shown however, that primary school teachers feel inadequately prepared to teach PE effectively (Fletcher & Mandingo, 2012). Efforts to provide these generalist primary school teachers with specialised training to equip them with the skills and confidence to promote FMS could be an important factor in addressing the FMS deficiencies outlined in chapter 3. One component of the Moving Well-Being Well (MWBW) intervention, outlined in chapter 5, attempts to address this by having the trained GAA coaches upskill the teachers within their school environments

Multicomponent interventions targeting FMS that are underpinned in a relevant theoretical framework have been shown to be the most effective (Kriemler et al., 2011; Craig et al., 2008). The MWBW intervention outlined in Chapter 5 is underpinned by the theory of constraints and self-determination theory, and is designed using the framework outlined by the Behaviour Change Wheel (Michie et al., 2011). The program is made up of multiple components, including family, community, teacher training, active classrooms and external provider components. The MWBW intervention sought to partner with one of the largest external providers in the primary physical education (PE) space in the Gaelic Athletic Association (GAA). Deployed through the GAA's existing network of community based coaches, Chapter 6 shows the intervention group showed a significant increase in FMS proficiency. While the control group also showed a significant increase from baseline to retention, this can be attributed to the growth and maturation of children's motor development, as depicted in chapter 3, and it's worth noting that at the retention stage the intervention group was still significantly more proficient than the control group. While this study highlights the impact a professional coach can have in improving FMS, the results also show that the MWBW intervention is effective in achieving significantly greater improvements than the primary PE curriculum alone. Given the links previously discussed between FMS, HRF, and increased PA participation, the MWBW intervention should be considered as an effective method to tackle the low levels of FMS proficiency prevalent in Irish primary school children.

To summarise, this thesis contributes to the field in several novel areas. The initial study gives a definitive snapshot of the FMs proficiency levels of Irish school children. The large sample size, as well as the wide range in age, will give researchers involved with FMS assessment in children of all ages a new dataset to compare to their own. The second study outlined in Chapter 4 gives the most in depth examination of the dynamical nature of the FMS and HRF relationship, and has not been done before, to the best of the authors knowledge. While some have used just a narrow range of FMS measures, and others just use one component of HRF as a proxy, this is the first which outlines the dynamic relationship of FMS and HRF across a wide age range, using a broad FMS assessment and all components of HRF. While the limitations of the intervention have already been mentioned, the pilot trial has shown encouraging signs and, with refinement, could represent the beginning of a solution towards addressing physical inactivity.

7.2 Research Strengths

This thesis introduces the reader to an array of themes relating to children of primary school going age, namely physical literacy, fundamental movement skills, health related fitness, multicomponent intervention, effective intervention design and deployment. While the MWBW program is not without limitation, these will be discussed later, there is strong evidence of innovative studies throughout this thesis, including the efficacy of the MWBW intervention in improving FMS proficiency. The various strengths are as follows:

The studies outlined in chapters 3 and 4 utilise a large cross-sectional data set (n = 2098) which encompasses the full age and class range of primary school children. The sample is reflects, as best as possible, the primary school landscape in Ireland, and accounts for factors such socioeconomic status, geography, gender and school ethos.

The studies outlined in this thesis provide an in-depth look at the physical competence component of the physical literacy construct, using gold standard assessment tools recommended from the literature. This approach was taken after recommendations from one the leading experts in the field on how to assess the core physical competence component.

An unique iPad application was designed and developed to collect the data required in the various studies outlined in this thesis. The app replaced the pen and paper process traditionally utilised in research of this nature (Ulrich, 2017). This allowed the researchers to collect large amounts of data due to the elimination of time spent manually inputting data, while cutting down on potential error through the manual data entry process. While the design and development of this application are outside the scope of this thesis, the app will provide future researchers a robust means of collection large amounts of data while still complying with GDPR and institutional ethical guidelines.

This thesis also evaluated the relationship between FMS and all the HRF components. This evaluation allowed for a deeper understanding of the dynamic nature of the relationships and has added to the value to the existing literature. While it gives important knowledge to researchers, particularly those who are interested in conducting research with children, it also informs the practitioners on the ground. Knowing that the relationship between FMS and the various HRF components is dynamic and strengthens with age, practitioners are better informed to better plan their activities to suit their intended outcomes.

A novel and culturally relevant intervention was designed and implemented for the Irish primary school cohort. This multicomponent design is unique in the fact that it partnered with the GAA and was able to use the existing infrastructure of community based coaches to both implement the intervention and upskill the teachers in the school setting. This was achieved through an extensive Continuous Professional Development (CPD) module that all participating coaches underwent (See appendix G).

The results reported in chapter 6 show significant intervention effects, highlighting not only the MWBW interventions efficacy in improving FMS proficiency, but also retaining these positive results six months later at the retention stage. These results showed that multicomponent nature of the intervention, including family, community, teacher training and active classroom components, is effective in an Irish primary school setting.

Finally, a significant strength throughout the thesis is the statistical analyses employed throughout. The author believes that the most appropriate, relevant analyses were used for each study presented here, and the increasing rigour of analyses utilised as the thesis progresses mirrors the authors progression as a researcher.

7.3 Research Limitations

The samples used in the studies described in chapter 3 and 4, while large, are cross-sectional, and as such cannot be used to confirm causal pathways. Future research should seek to be longitudinal in nature, to see if the results depicted here hold true over time.

While collecting the FMS data, participants are allowed one practice trial, before partaking in the two trials in which they are assessed. Due to the fact that the intervention study collected FMD data at three timepoints within a six month period, there is a possibility of a learning effect.

During the FMS data collection, participants receive a correct demonstration of the skill being assessed by a trained member of the research team. There is the possibility that if an individual's peer performs the skill incorrectly prior to their own performance, the individual may mimic their peer instead of the correct performance demonstrated by the researcher.

Its recognised that the cross sectional nature utilised in the initial two studies is a limitation, and that it cannot be used to discern causal pathways. Building upon this, longitudinal research would verify, or refute, the direction of the relationships put forward in this thesis. A delimitation of this study is the focus on FMS , and the relationship FMS has with HRF, and the potential health benefits. Future studies should consider confounding variables, such as an objective measure of PA, to expand the breadth of the analyses put forward here.

The sample size retained at the retention stage of the intervention study was not as high as desired. This was due to the fact that two schools who participated in the study are classed as junior schools. This means that they only cater for five to seven year olds (junior infants to first class in an Irish primary school context). Upon completion of junior school, the students involved in the study were scattered over several schools, and as such, the logistics of reassessment at this stage was unfeasible.

While every effort was made to ensure that the participating schools adhered to the intervention as best as possible, they were not monitored by the research team. Principals and teachers were instructed to contact the researcher if any issues arose, and also had the support of the GAA coach who was implementing a component of the intervention in their respective schools. Future versions of this intervention should seek to implement a robust surveillance of intervention fidelity, including surveillance of protocol adherence of the teacher, coaches, and parents.

I was clear in outlining my philosophical position early in the thesis and it was also mentioned that my previous experiences could influence the interpretations outlined in the thesis. While this could have had a potential bias on the narrative, this was ameliorated through implementing strong rigour throughout the research design, particularly through the verification process provided by the supervision of three senior academics.

7.4 Future direction for the Moving Well-Being Well project

The MWBW exploratory trial as depicted in chapter 6 is an effective intervention to improve FMS proficiency in primary school children. Throughout the data collection for the multicomponent intervention, at each of the three time point, other components of the physical literacy (PL) construct were assessed, namely, motivation, confidence and perceived movement competence. Although the assessment and analyses of these variables goes beyond the scope of this thesis, it is important that they are assessed and brought together in order to gain a deeper understanding of how these components interact. Cross-analyses of this data will allow for examination of the relationships between these variables in a primary school population, and potentially inform the growing body of research investigating PL.

While FMS are purported to be made up of locomotor, object control and stability skills (Gallahue & Ozmun, 2006), many studies fail to include stability skills within their assessments of FMS (Rudd et al., 2015). These stability skills are often described as the most basic of those included in the FMS family (Gallahue et al., 2012), but some would argue that even those studies that include a stability measure have not measured it adequately (Rudd et al., 2015). While the BOT-2 short form utilised in this thesis is a valid and reliable measure, and contains elements of static and dynamic balance, future research should investigate other forms of stability assessment that categorise the various stability skills to gain a deeper understanding of children's FMS development (Gallahue et al., 2012; Rudd et al., 2015).

Chapter's 3 and 4 contain data and analysis collected from the initial widespread data collection outlined in this thesis. The methods in both chapters outline that data were collected taking several school demographics into consideration, including; geographical (urban and rural), school ethos (catholic, non-denominational, church of Ireland, etc.), gender (mixed or single gender schools), school size (small, medium, or large), and socioeconomic status (DEIS or non-DEIS). While ideally all of these variables would be analysed and results documented in both studies, it was deemed by the author that the inclusion of all variables in the analyses would be too unwieldly and unfocused to document in this thesis. Future studies should seek to delve deeper into this data and produce results outlining any differences schools demographics has on the results presented here.

Future studies should seek to strengthen the MWBW intervention, and should consider building on the findings presented here during the exploratory trial. The MWBW intervention has to date only taken place in urban schools. In order to ensure it is effective in all school types, future studies must measure its efficacy in all primary school settings in Ireland. The next iteration of the MWBW intervention should take into account the limitations outlined in this thesis, namely ensuring that robust intervention fidelity measures are implemented. In addition a thorough process evaluation should be carried out on any future intervention, in order to make the MWBW intervention sustainable for national dissemination. Future studies around the MWBW program should entail the expansion of the intervention to a feasibility study entailing a large sample size, with the intention of leading to a future randomised control trial (RCT).

While the MWBW intervention is unique in that it is underpinned by a refraction of movement experiences and PL outcomes through the marrying of the theory of constraints and self-determination theory, other research has attempted to adopt similar approaches. Roberts and colleagues (2018), use a constraints led approach (CLA) and a play-based curricula in attempting to develop key principles of PL. Other studies highlight the importance the environment can have on the development of physical literacy and its components (Rudd et al., 2019). While the MWBW intervention has been successful in improving FMS proficiency, it is expected that the version presented in this thesis will evolve through various iterations. The manner in which we judge its success may also change, with recent studies in particular questioning the traditional process and product based FMS assessments (Hulteen et al., 2019; Rudd et al., 2015). The FMS assessments employed are human movements and can be affected by physiological (Cattuzzo et al., 2016), maturational (Hands et al., 2009), psychological (Robinson et al., 2015), and environmental constraints (Özdirenç, Özcan, Akin, & Gelecek, 2005). Some projects, such as Project Flame, seek to combine the FMS with functional movement assessments (Lester & O'Brien, 2018). Looking to the future, any development of the MWBW intervention should also seek to use the most suitable and valid tools measurement tools available.

Finally, the MWBW project is unique from other interventions in that it is partnered with the GAA. The GAA are the largest sporting body in the country and have a network of highly trained, capable, and professional staff throughout the country. Building on this relationship is paramount if the MWBW program is to be implemented at a national scale. The preliminary results from this exploratory trial show report positive FMS findings, and if any future RCT is successful, the final MWBW intervention could be a practical, scalable, sustainable and cost effective intervention that can be disseminated nationally, potentially impacting primary school children's health at a societal level.

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Appendices

Appendix A: Examples of FMS Specific Lesson Plans from the Moving Well-Being Well Intervention Resources

Moving Well Being Well

Lesson 3

Skills Focus

Skipping
Catching
Throwing
Jumping

This pack contains activities from the PDST Move Well, Move Often Resource.

The other side of this card contains a teacher aid that should accompany this lesson. This aid is aimed at assisting a teacher delivering the lesson.

Equipment required

Cones
Beanbags
Tennis Balls
Balls of various sizes

DCU

Insight

This project is being run by the School of Health and Human Performance in Dublin City University, in collaboration with the Insight Centre for Data Analytics

Supported by

GAA

ÁTH CLIATH

Teachers Notes:

FREEZE

Description of Activity

Pupils find a space in the playing area. Invite them to skip freely around the playing area. On a signal, or when the teacher calls 'freeze', pupils must perform a balance and hold it for a count of five. After they reach the number five, they continue skipping freely around the space. Balancing prompts may include: balance on one foot, balance on two body parts, balance on a large body part, balance on one hand and one foot etc. Pupils perform a different balance each time.

Variations

- Vary the locomotor skill used to move around the area, e.g. hopping, side stepping.
- As the activity progresses introduce partner work and group balances.
- Arrange pupils in pairs, with one skipping and the other watching. Give them clear guidelines to provide each other with feedback on their skipping technique. The observing pupils provide the suggestions for each balance. Alternate roles each time.

Equipment

An open playing area

- Explore a theme for each balance, e.g. animals, superheroes etc.
- Pause the activity at intervals to focus on the specific teaching points for skipping in the lesson. Invite a pupil to demonstrate correct technique, allow pupils to practise in isolation and then return to the activity. Provide feedback to individuals while they perform the skipping action during the activity.

- In your PE journal, create a new game that involves skipping. Show your friends how to play it in the yard.

scipeáil • reoigh • cothromaíocht • baill choirp

Resources from the PDST PE Resource 'Move Well, Move Often'

BOUNCE PASS

ATHLETICS GAMES

Description of Activity

Arrange pupils in pairs and invite them to find a space in the playing area where they are not in contact with other pupils. Pupils face each other, approximately five metres apart and place a spot marker on the floor in the middle, equidistant from each pupil. Pupil A bounces the ball on or near the spot for their partner to catch. Pupil B then repeats the action.

Variations

- Alternate the hands used to bounce and catch e.g. bounce with two hands and catch with one or bounce with one hand and catch with the other.
- Vary the size or shape of the ball.

Equipment

A hard playing surface, spot markers, balls of various sizes including tennis balls

- Ensure pairs are evenly spaced and that pupils are not throwing across the path of another pair.
- At regular intervals pause the activity and discuss today's teaching points for catching. Invite a pupil to demonstrate correct technique, invite pupils to practise in isolation and then return to the activity.

- In your PE journal, draw a picture of a game that involves catching.

preabphas • gabháil agus caitheamh • spás le dromchla crua • ag obair i mbeirteanna • liathróid a phreabadh • malartaigh na lámha • forleathnú

PDST Resources from the PDST PE Resource 'Move Well, Move Often'

CATCH THE LEADER

ATHLETICS GAMES GYMNASTICS

Description of Activity

Arrange pupils in groups of eight to ten and invite them to form a circle. The leader stands in the centre of the circle with a ball. The leader throws their ball to a pupil in the circle, who throws it back to them, and this action continues around the circle in a clockwise direction until every pupil has had a turn. After the last turn, the leader gives the ball to the next pupil and the activity continues until each pupil has had a turn as leader.

Variations

- Pupils balance on one leg after throwing the ball back to the leader.
- Pupils complete three jumps for height after they have thrown the ball back to the leader.
- Invite two leaders to stand back to back in the centre of the circle. The game continues as before, but now the passes must be completed at a faster pace.
- Increase or decrease the size of the circle.
- Vary the manipulative skill used to move the object, eg. kicking, striking with an implement, striking with the hand etc.

Equipment

An open playing area, balls of various sizes

- Pupils awaiting a turn should extend their hands outwards in anticipation of the ball.
- Pause the activity at intervals to focus on the specific teaching points for throwing in the lesson. Invite a pupil to demonstrate correct technique, and then return to the activity. Provide feedback to individual pupils as they practise throwing during the activity.
- Emphasise the importance of teamwork and cooperation - a good throw is necessary for a good catch!

- Practise throwing at home using a teddy bear. Investigate whether this is easier or more difficult than throwing a ball.

ochtar nó deichniúr • beirt cheannaire • ciorcal • droim le droim • ag caitheamh na liathróide

Resources from the PDST PE Resource 'Move Well, Move Often'

DISCOVER JUMP

ATHLETICS DANCE GAMES GYMNASTICS

Description of Activity

Give each pupil a spot marker, and invite them to find a space in the playing area where they are not in contact with anyone else. Each pupil places their spot marker on the floor and stands on the spot. Invite pupils to practise jumping onto and off their spot using some of the following instructions:

- Jump very fast or slow
- Jump like a giant or a frog
- Jump with stiff legs and arms
- Jump up and down keeping your arms out from your side
- Jump on and off your spot with legs apart and land with feet apart
- Start on your spot and jump three times forward in a straight line
- Start on your spot and jump around in a wide circle until you return to your spot

Variations

- Invite pupils to create their own different types of jump actions.
- Invite pupils to work in pairs to create a jump sequence.
- Add a low object to jump over e.g. rope, cone, beanbag.

Equipment

An open playing area, spot markers, ropes, cones, beanbags

- **Ensure there is adequate space between pupils to allow them to jump on and off their spot without crossing the path of another pupil.**
- **Pause the activity at intervals to focus on the specific teaching points for jumping in the lesson. Provide feedback to individuals while they perform the jumping action during the activity.**

- **In your PE journal, draw a picture of you jumping.**

ag seasamh ar spota • léim tapaidh • léim mall • ciúin • glórach • lámha amach

PDST

Resources from the PDST PE Resource 'Move Well, Move Often'

Lesson Notes:

What went well:

What didn't work so well:

Targets for next lesson:

LESSON 3 - FREEZE — 5 MINS

Learning Intention:
Child is learning to skip in a fluid motion through swinging the opposite leg forward for momentum

Key Questions:
What type of balance could we do?
Can you hold for more than 5 seconds?

FMS Differentiation and Success Criteria

1. Step 1: STEPS & HOPS ON ONE FOOT
2. Step 2: OPPOSITE ARM TO LEG
3. Step 3: SWINGS LEG FOR MOMENTUM
4. Step 4: ALTERNATES ARMS AND LEGS FLUID SKIPPING

LESSON 3 - CATCH THE LEADER — 10 MINS

Learning Intention:
Child is learning to co-operate within a group and identify that their throw can go further if they rotate their torso when throwing

Key Questions:
How can we improve our throw?

FMS Differentiation and Success Criteria

1. Step 1: THROW STARTS OVER SHOULDER
2. Step 2: STEPS WITH OPPOSITE FOOT TO THROW
3. Step 3: ROTATES TORSO AND ARM EXTENDS BEHIND
4. Step 4: ARM LAGS WHEN THROWING

LESSON 3 - BOUNCE PASS — 10 MINS

Learning Intention:
Child is learning to adjust their body to reach hands out to catch a bouncing ball

Key Questions:
Can you make it easier/harder for your partner?
Can you use a different ball?

FMS Differentiation and Success Criteria

1. Step 1: CATCHES INTO CHEST
2. Step 2: CATCHES WITH JUST HANDS
3. Step 3: ADJUSTS FEET & HANDS TO CATCH
4. Step 4: CATCHES WITH EITHER HAND

LESSON 3 - DISCOVER JUMP — 5 MINS

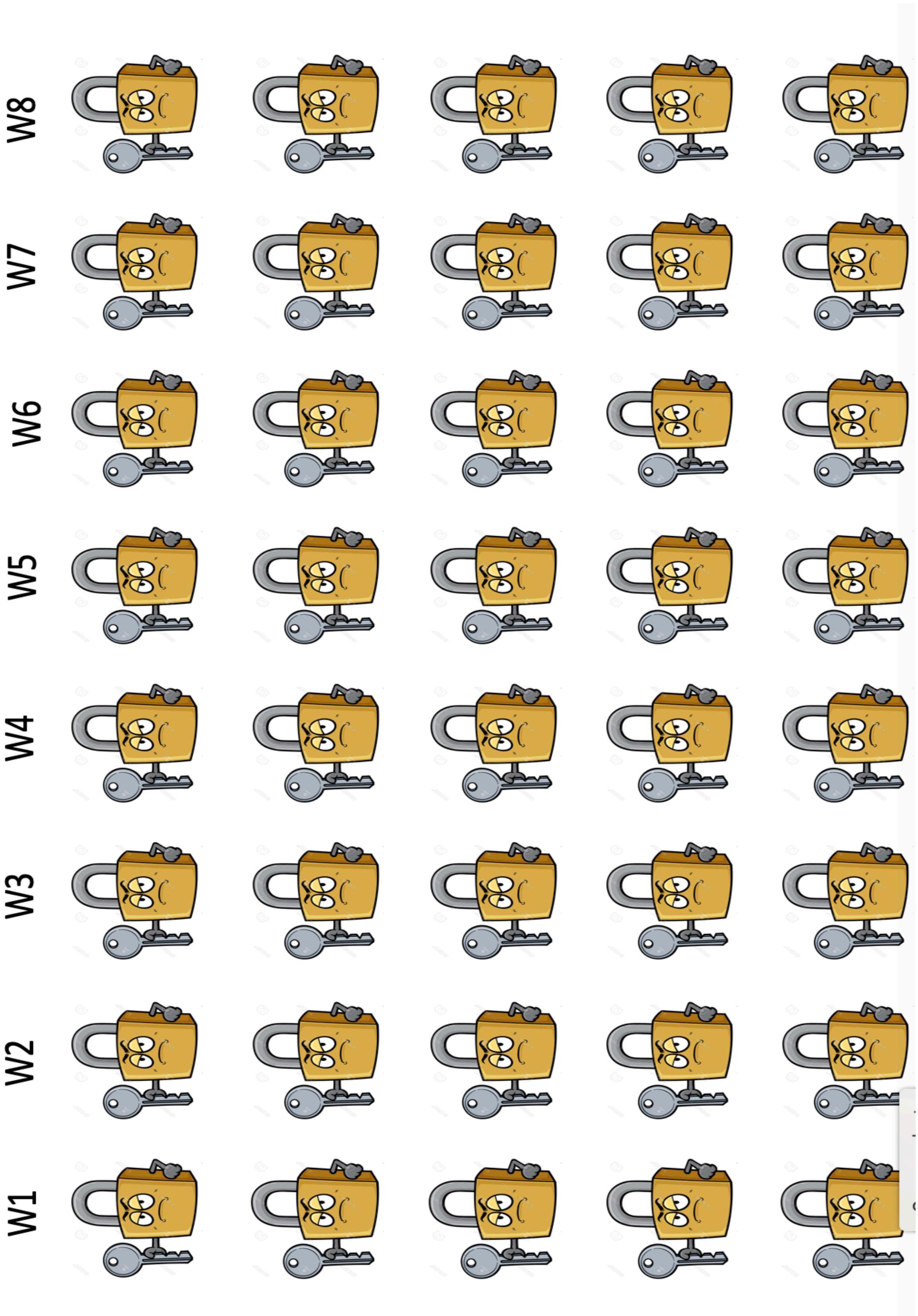
Learning Intention:
Child is learning to appreciate that bending knees before jumping off two feet can help them go further

Key Questions:
Which is the easiest jump to do?
Can you bend your knees before jumping?

FMS Differentiation and Success Criteria

1. Step 1: JUMP WITH BOTH FEET AT SAME TIME
2. Step 2: CROUCHES BEFORE JUMPING
3. Step 3: ARMS SWING BEHIND BEFORE JUMP
4. Step 4: ARMS SWING FORWARD, LEGS FULLY EXTEND

Appendix B: Examples of the Active Learning classroom component from the Moving Well-Being Well Intervention Resources



Frog Hunches

- Start standing up straight
- Hunch down like a frog , bending your knees and touching the floor with your hands
- Go from standing to hunched position and back 10 times

Starfish Jumping Jacks

- Stand feet together
- Jump and spread your feet apart, move your hands out and overhead like the starfish
- Jump again , bring feet together and arms back to side

- Do it for 20 seconds
    - What happens to your chest? Why does this happen?

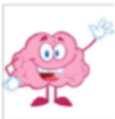
Appendix C: Examples of the Home Activity component from the Moving Well-Being Well Intervention Resources

ACTIVITY - JUMPING

DESCRIPTION OF ACTIVITY

Ask someone at home to join in

1. Stand with your feet together and jump as high as you can. Be sure to land with both of your feet at the same time
2. Does crouching down before you jump help you jump higher?
3. Does using your arms help with your jump?
4. Ask mammy and daddy to do it too, who has the highest jump?
5. Can you think up any high jumping games? Play for 1 minute with someone at home



BRAINY BITS

How many minutes each day should you and other children do physical activities?

This is anything that makes your heart beat faster or makes you breath faster, like walking fast or running.

Use the clock and draw your answer in

Sometimes children watch television, play video games or play on the computer and on a phone.

What is the most time that children should look at a screen each day?

Do not count the time that you have to look at a screen to do your homework.

Use the clock and draw your answer in

JUMPING

Moving Well Being Well

ACTIVITY - HOPPING

DESCRIPTION OF ACTIVITY

Ask someone at home to join in

1. Stand on one foot and hop around the room.
2. Can you do it on the other foot? Which foot is the best?
3. Does using your arms help with your hop?
4. Ask someone to try it too, can they hop well on both feet?

BRAINY BITS

Physical activity is about making friends and fun. Fill in the blanks

Should not ***Stop*** ***Should*** ***Keep going***

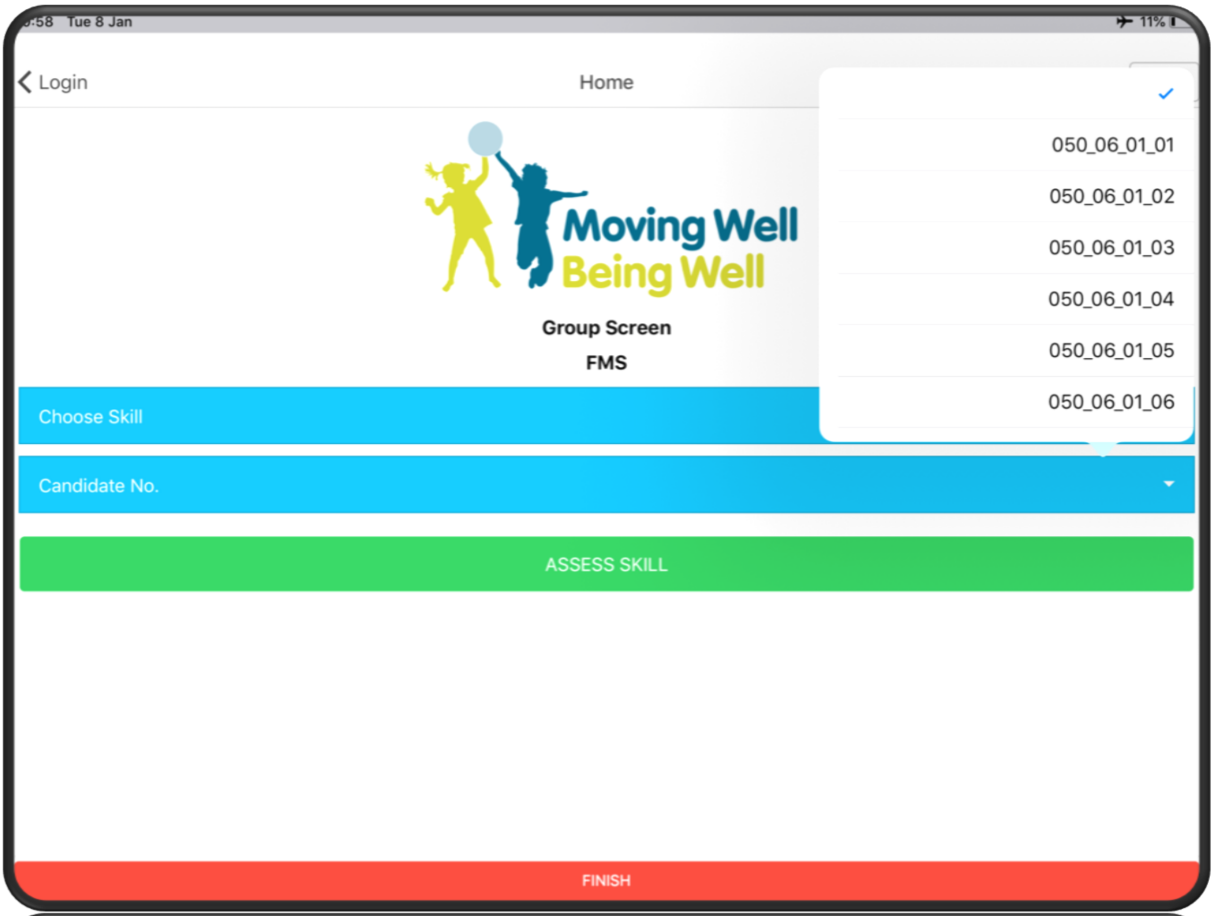
If someone falls in front of you while running a race and they are hurt, you should ______________________ and check if they are alright.

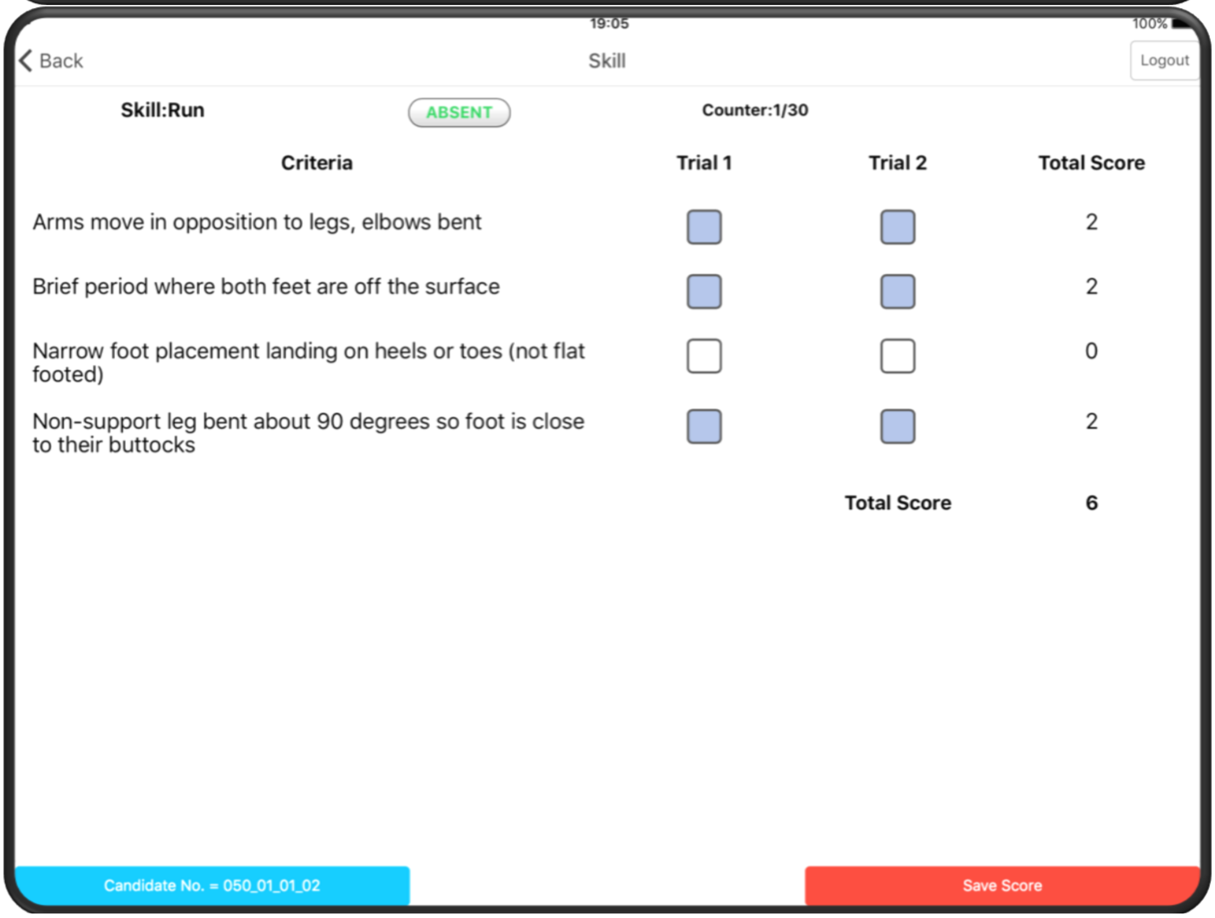
When playing sport, you cannot win all the time. If you lose, the important thing is to ____.

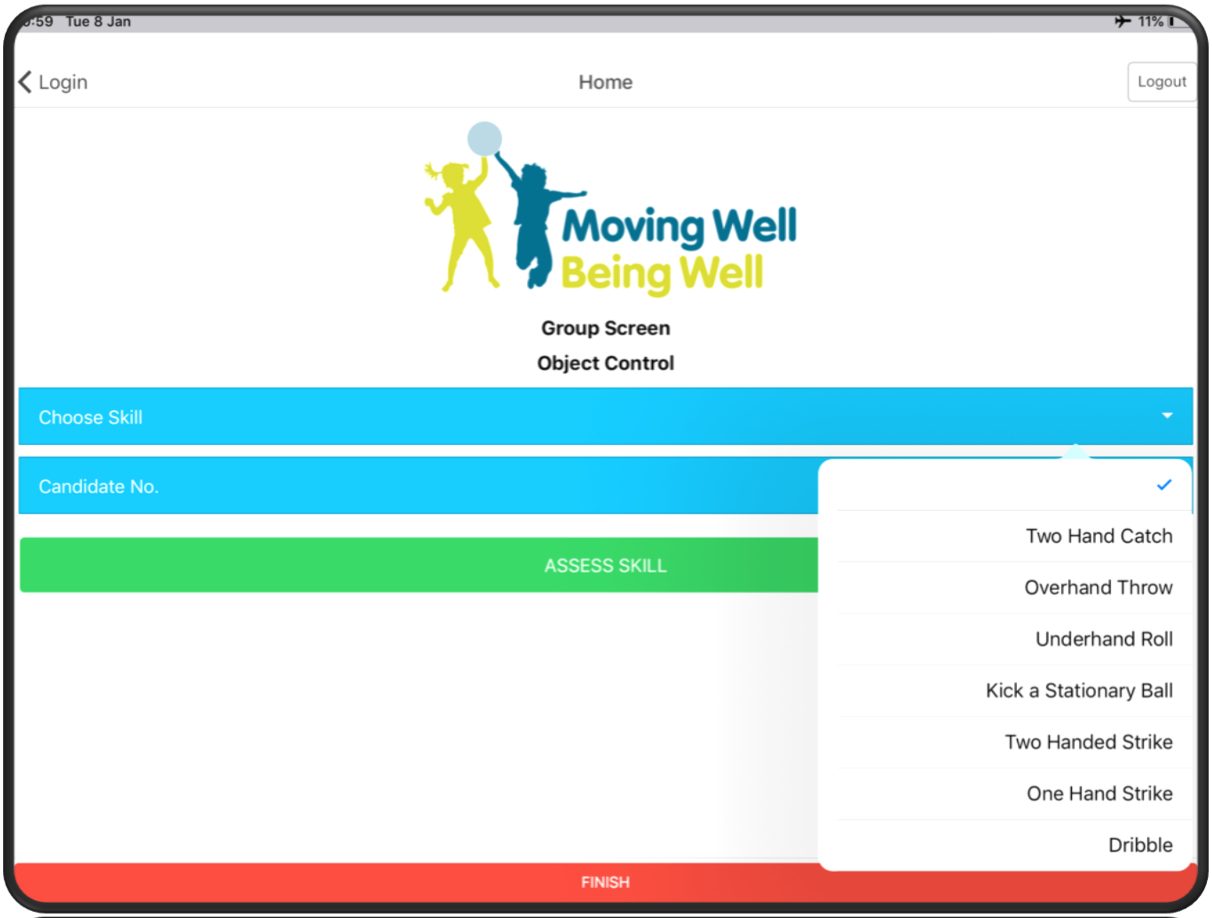
Everyone makes mistakes. If you see someone make a mistake, you ________ go over and see if there is any way that you could help.

Winning is nice. Remember when you win that you ____________________ laugh at the losers.

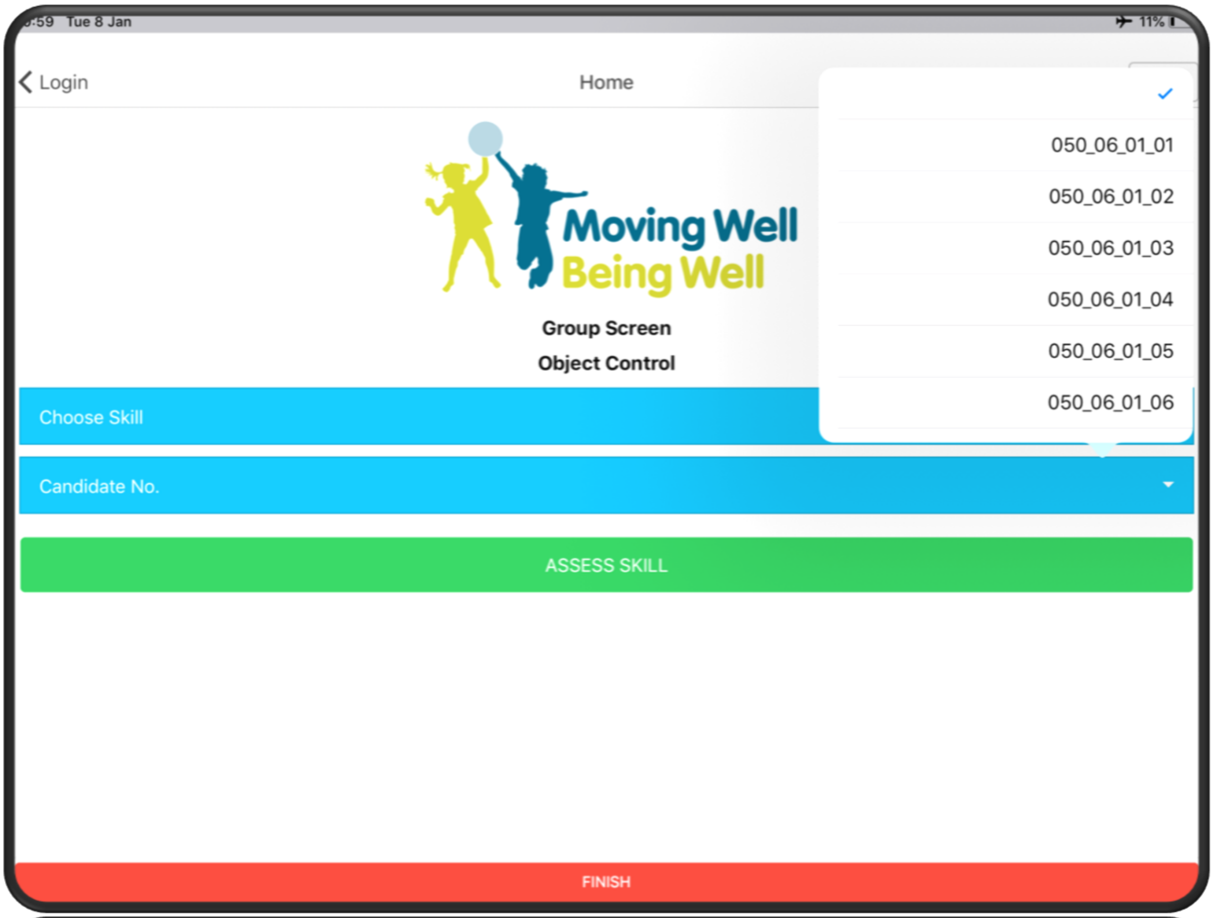
Appendix D: Screenshots of the iPad application developed as part of the Moving Well Being Well project.

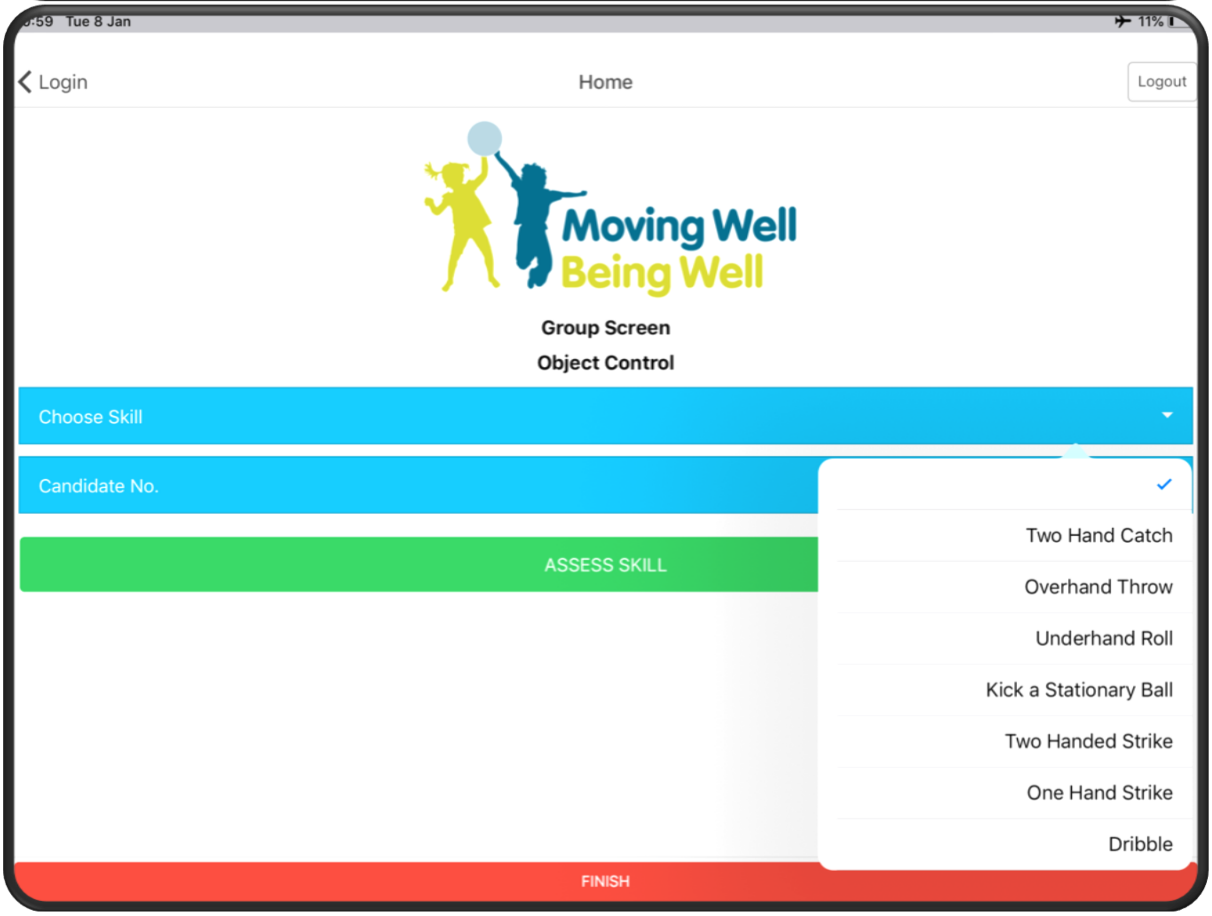





Login
Home
Logout
Moving Well
Being Well
Group Screen
Object Control
Choose Skill
Candidate No.
ASSESS SKILL
Two Hand Catch
Overhand Throw
Underhand Roll
Kick a Stationary Ball
Two Handed Strike
One Hand Strike
Dribble
FINISH


19:09
100%
Login
Home
Logout
Moving Well
Being Well
Group Screen
FMS
Object Control
HRF
Balance
GAA
UPLOAD RESULTS


Tue 8 Jan
Login
Home
Moving Well
Being Well
Group Screen
Object Control
Choose Skill
Candidate No.
ASSESS SKILL
050_06_01_01
050_06_01_02
050_06_01_03
050_06_01_04
050_06_01_05
050_06_01_06
FINISH


Tue 8 Jan
Login
Home
Logout
Moving Well
Being Well
Group Screen
Object Control
Choose Skill
Candidate No.
ASSESS SKILL
Two Hand Catch
Overhand Throw
Underhand Roll
Kick a Stationary Ball
Two Handed Strike
One Hand Strike
Dribble
FINISH

Appendix E: Current trends in the Irish Primary PE Curriculum

The Irish primary school physical education is made up of six strand, namely; dance, athletics, games, aquatics, gymnastics, and outdoor and adventure activities. Full details of the curriculum are detailed in the link below.
https://www.curriculumonline.ie/getmedia/ca8a385c-5455-42b6-9f1c-88390be91afc/PSEC05_Physical-Education_Curriculum.pdf

The curriculum states that children should receive a minimum of one hour per week, and that all strands should be allocated equal time in each school year. Research has shown that the mandated 60 minutes of PE curricular time is not being delivered in some schools across Ireland (Woods et al. 2010, Department OF Education and Skills 2016, Research Work Group for Ireland's Report Card on Physical Activity in Children and Youth 2016). Figures would suggest that Irish children receive on average only 46 minutes of PE each week (Woods et al. 2010). This figure ranks poorly in comparison to the global average of 103 minutes weekly (UNESCO 2014) and European average of 112 minutes physical education per week (European Commission/EACEA/Eurydice 2013). To put these figures in perspective, Irish primary schools currently spend only 4% of prescribed available teaching time on Physical Education, the lowest of any European county (European Commission/EACEA/Eurydice 2013).

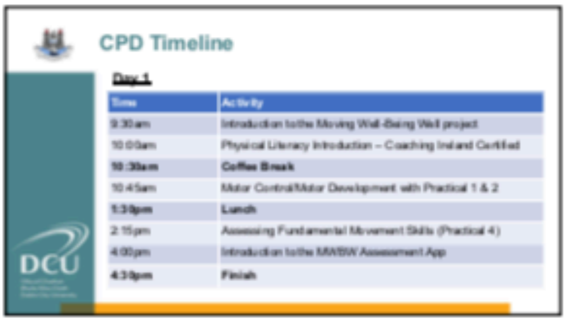
Research from the SHAPE study (2010) recommends that, in order to develop physical literacy, children should participate in an instructional physical education program for a minimum of 150 minutes weekly throughout the school year. The European Commission Expert Group on Health-enhancing physical activity recommends that children engage in PE on daily basis for approximately 1 hour (European Commission for Sport 2015). Results from a survey conducted by the Irish Primary Physical Education Association (IPPEA) indicated that members would support significant increases in the allocation of time to PE in primary schools. The IPPEA believes that 150 minutes of PE should be provided on a weekly basis to all children in Irish primary schools in order to achieve the most beneficial PE programme.

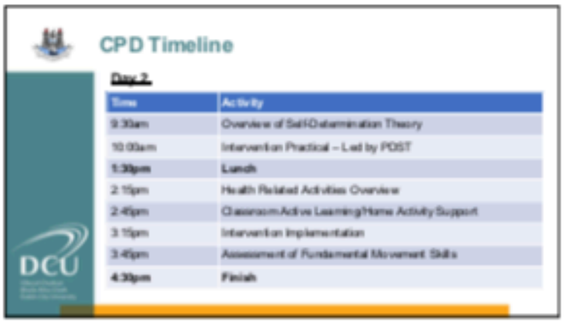
Appendix F: GAA Coach Recruitment

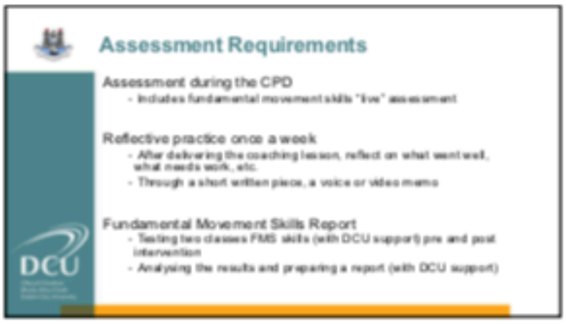
The GAA is Ireland's largest sporting organisation and promotes indigenous Gaelic games such as Gaelic football, hurling, camogie, handball and rounders (GAA, 2019). The GAA are the largest external provider operating in primary schools, providing specialised sport specific support through their community based GAA coaches. External providers are often used in primary schools to support PE in primary schools. The Moving Well-Being Well (MWBW) project is in partnership with both the Gaelic Athletic Association (GAA), and the Dublin branch of the GAA. Through these partnerships, the pilot MWBW intervention was deployed through a network of trained GAA coaches in the Dublin region.

Coaches were recruited through Dublin GAA and some inclusion criteria had to be met in order for a coach to participate. Only coaches who had completed their Tutor training certification. The GAA have an extensive coach education programme and the full time coaches are required to deliver these programmes. Prior to delivering these programmes, coaches must undergo formal certification in tutor training through Coaching Ireland. Coaching Ireland, a subsidiary of the governing body for sport in Ireland, are the national certification body for all sports in Ireland. The coaches then had to undergo an intensive three day training programme in DCU in understanding physical literacy, FMS assessment, and the MWBW intervention implementation. Full details of the training are outlined in Appendix G.

Appendix G: Continuous Professional Development course delivered to coaches implementing the Moving Well-Being Well intervention



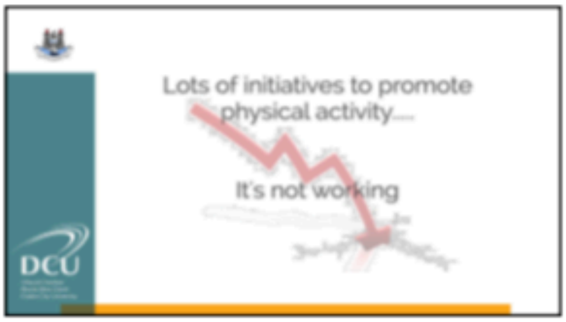





Question
What do you think are the biggest reasons for intervening in primary schools?
DCU

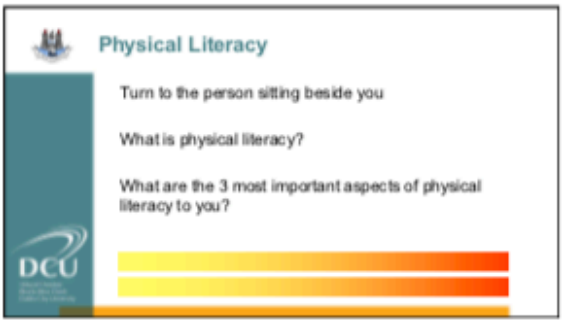

Background
"Ireland to be the most obese nation in Europe by 2030"
"One in four children overweight or obese"
DCU


DCU

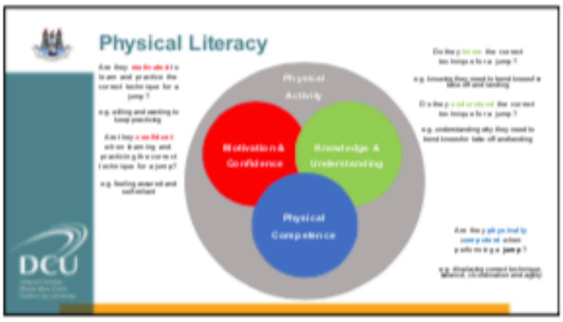

Lots of initiatives to promote physical activity….
It's not working
DCU


Moving Well-Being Well Project Overview
2,148
children assessed
12
counties across all four provinces
44
schools
100
classes from Junior Infants to 6th Class
10,000+
kilometres travelled
DCU


What have we measured?
FMS Proficiency
Perceived FMS Competence
Height, Weight (BMI) and Waist Circumference
Strength – Grip and Plank
Flexibility
VO2 Max
Physical activity – Self reported, parent reported and pedometers (sample)
Motivation
Self Efficacy
Knowledge and understanding*
Wellbeing
Body Image
Neurocognitive assessment
Teacher questionnaire
Parents questionnaire
All validated instruments for measurement
DCU

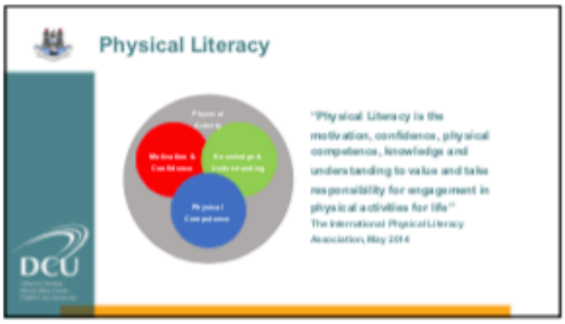

Physical Literacy
Turn to the person sitting beside you
What is physical literacy?
What are the 3 most important aspects of physical literacy to you?
DCU


What motivates children to be physically active?
Motivation & Confidence
Knowledge & Understanding
Physical Competence
The physical competence or ability to perform a a specific task or activity
DCU


Physical Literacy
Physical Activity
Motivation & Confidence
Knowledge & Understanding
Physical Competence
DCU


Physical Literacy
Motivation & Confidence
Knowledge & Understanding
Physical Competence
"Physical Literacy is the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life"
The International Physical Literacy Association, May 2014
DCU


Physical Literacy Journey
DCU


Physical Literacy
Motivation & Confidence
Knowledge & Understanding
Physical Competence
"Physical Literacy is the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life"
The International Physical Literacy Association, May 2014
DCU


Fundamental Movement Skills
The foundational movements needed to progress to the more specialised and complex skills used in play, games and specific sports
DCU

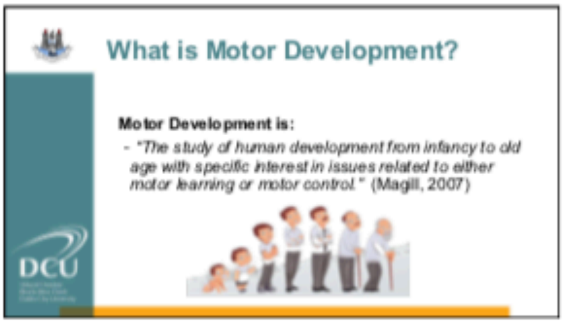

Fundamental Movement Skills - Results
DCU

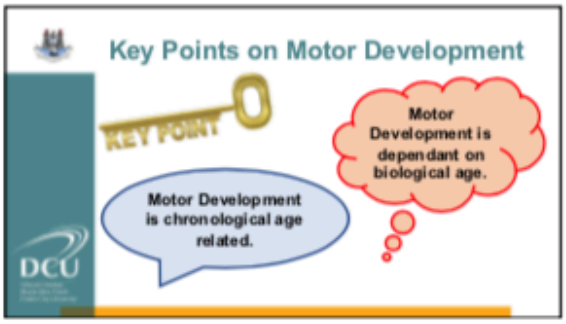

Fundamental Movement Skills - Results
FMS Progression across Primary School
5
6
7
8
9
10
11
12
Age
DCU

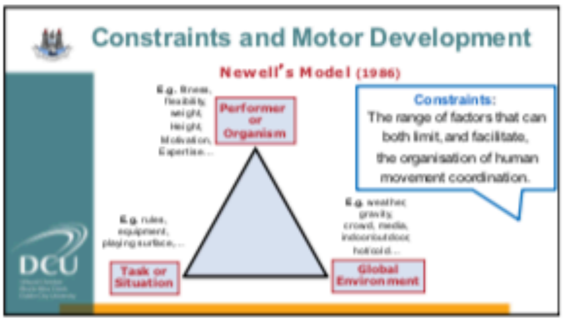

Motor Development, Growth & Maturation
DCU

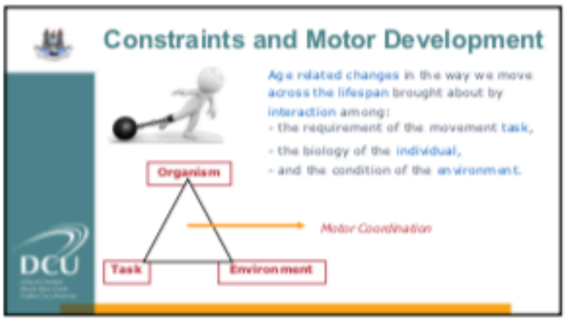

Aims
How can you help someone:
- To learn a new skill
- To become an "expert" at a skill.
- We will try to achieve these aims with kids!
DCU

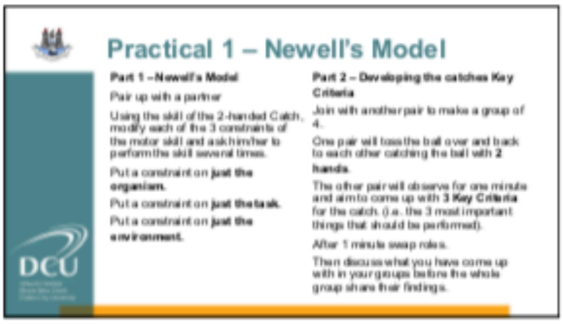

To achieve these aims we have to
- Know and understand the different theories of movement.
- Observe and analyse human movement.
- Interpret the observed movement and provide efficient feedback.
- Correct errors of the current motor skill performance.
Feedback
DCU


What is Motor Development?
Motor Development is:
- "The study of human development from infancy to old age with specific interest in issues related to either motor learning or motor control." (Magill, 2007)
DCU


Key Points on Motor Development
KEY POINT
Motor Development is chronological age related.
Motor Development is dependant on biological age.
DCU

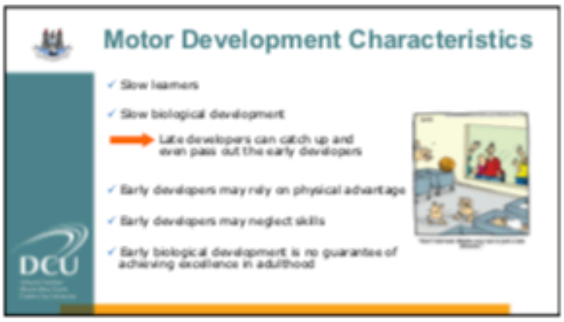

Constraints and Motor Development
Newell's Model (1986)
E.g. fitness, flexibility, weight, Height, Motivation, Expertise…
Performer or Organism
Constraints:
The range of factors that can both limit, and facilitate, the organisation of human movement coordination.
E.g. rules, equipment, playing surface,…
Task or Situation
E.g. weather, gravity, crowd, media, indoor/outdoor, hot/cold…
Global Environment
DCU


Constraints and Motor Development
Age related changes in the way we move across the lifespan brought about by interaction among:
- the requirement of the movement task,
- the biology of the individual,
- and the condition of the environment.
Organism
Task
Environment
Motor Coordination
DCU


Practical 1 – Newell's Model
Part 1 – Newell's Model
Pair up with a partner
Using the skill of the 2-handed Catch, modify each of the 3 constraints of the motor skill and ask him/her to perform the skill several times.
Put a constraint on just the organism.
Put a constraint on just the task.
Put a constraint on just the environment.
Part 2 – Developing the catches Key Criteria
Join with another pair to make a group of 4.
One pair will toss the ball over and back to each other catching the ball with 2 hands.
The other pair will observe for one minute and aim to come up with 3 Key Criteria for the catch. (i.e. the 3 most important things that should be performed).
After 1 minute swap roles.
Then discuss what you have come up with in your groups before the whole group share their findings.
DCU


Components of Catching
1. Child's hands are positioned in front of the body with the elbows flexed
2. Arms extend reaching for the ball as it arrives
3. Ball is caught by hands only
DCU


Constraints and Motor Development
Motor Learning
Learning may be defined as the set of underlying processes associated with practice leading to relatively permanent behavioural changes
Motor Development
Includes learning but also includes age related changes in the biology of the individual which influence the way we move
When?
Most obvious in childhood, adolescence and old age
DCU


Motor Development Characteristics
Slow learners
Slow biological development
Late developers can catch up and even pass out the early developers
Early developers may rely on physical advantage
Early developers may neglect skills
Early biological development is no guarantee of achieving excellence in adulthood
DCU


Phases of Skill Development from Infancy
Why do we do Physical Activity?
DCU


Phases of Skill Development from Infancy
Why do we do Physical Activity?
DCU


Phases of Skill Development from Infancy
Why do we do Physical Activity?
DCU

Fundamental Movement Phase

Key Characteristics

- Most skills have the potential to be developed by about 6 years

CATEGORIES OF FUNDAMENTAL SKILLS		
Locomotor	Object Control	Balance & Stability
Basic Running Walking Leaping Jumping Hopping	Propelling Throwing Kicking Striking Bouncing	Axial Stretching Bending Twisting Swinging
Combinations Galloping Sliding Skipping	Receiving Catching Trapping	Static & Dynamic Upright static balances Inverted static balances Rolling Starting Stopping

Fundamental Movement Phase

Key Characteristics

- Most skills have the potential to be developed by about 6 years.
- Form the bases for learning of sport specific skills of specialized movement phase.
- Many people don't ever reach full development because of lack of practice and teaching.
- Critical period refers to the idea that if learning of certain skills does not take place within a certain time frame they will never be learned effectively.

Fundamental Movement Phase

Developmental Stage of FMS

3 stages (Gallahue, 1996)

Initial (2-3 years approx)
Onset of pattern, poor control, parts of sequence missing, rhythm and co-ordination lacking

Elementary (4-5 years approx)
More parts present, better rhythm and co-ordination

Mature (5-7 years approx)
All parts present, good rhythm & co-ordination, mechanically efficient.

Fundamental Movement Phase

Developmental Stage of FMS

Charting of Development of FMS

Quantitative outcome assessment:

i.e. distance, height, speed

for throwing, jumping, running, etc…

**ASSESSING
QUANTITATIVE CHANGES
IS NOT ENOUGH
!!!**

Fundamental Movement Phase

Developmental Stage of FMS

Charting of Development of FMS

Distance = 13m

Distance = 13m

Fundamental Movement Phase

Developmental Stage of FMS

Charting of Development of FMS

- Sequences of **qualitative** (pattern) changes in development of FMS have to be identified.

- Criteria for stages of development.

- Actions patterns of body parts described and categorised into stages of developmental sequences.

Fundamental Movement Phase

Developmental differences

- Between individual differences
Rate of development in skills varies between individuals.

- Between skill differences
A child may be at mature levels in some skills and at initial or elementary in others.

- Within skill differences
A child may be a mature stage in leg action of a skill while at elementary level in upper body action.

Practical 2 – Jumping

INSTRUCTIONS

Use the developmental sequence of standing long jump (see Table 1) and the observation plan (see Table 2) to guide your decisions about the jumpers leg action and arm action.

Pair up with two partners

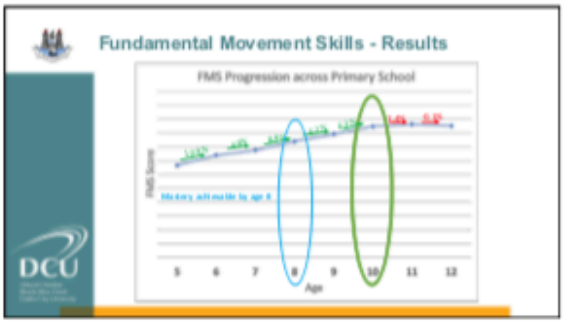
Task 1: Ask your partner to jump as far as he/she can.

Task 2: Ask your partner to jump as far as he/she can after taking a 4m run-up.

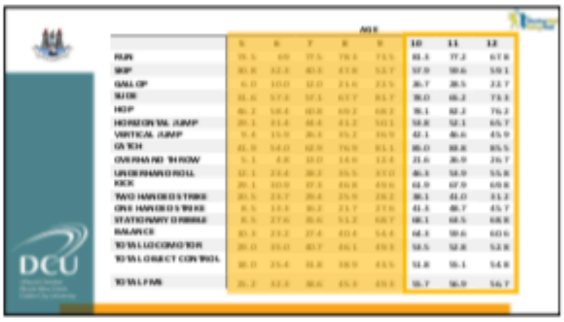
Task 3: Ask your partner to jump as far as he/she can when holding a weight in each hand (no run up).

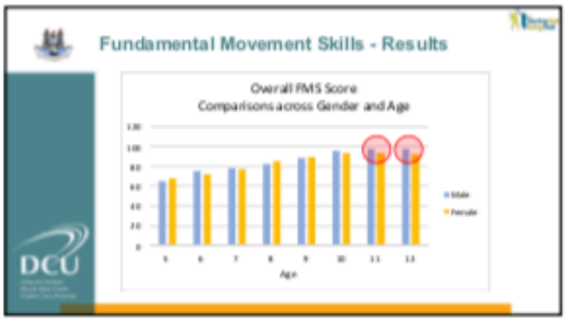
Note: To assess the developmental level of your partner correctly, he/she will have to do each task several times.

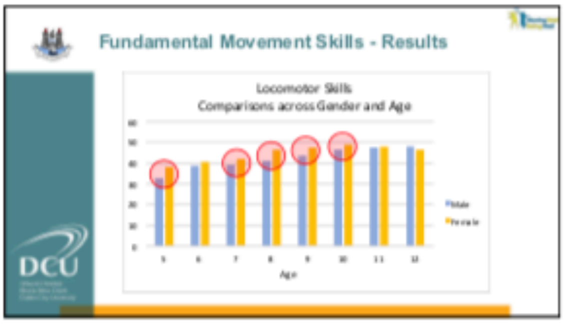
Level of Development of Irish Children at Fundamental Movement Skills

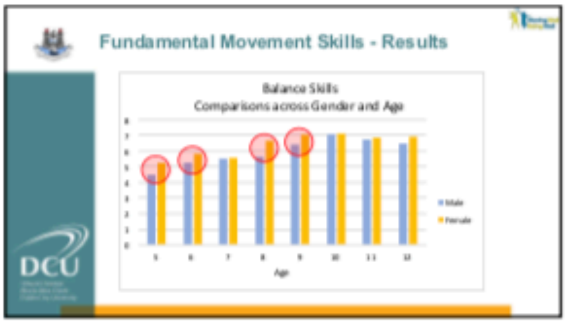

Fundamental Movement Skills - Results
FMS Progression across Primary School
Age

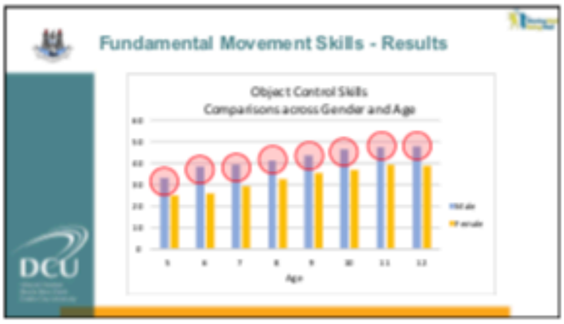

Fundamental Movement Skills - Results




Fundamental Movement Skills - Results
Overall FMS Score
Comparisons across Gender and Age
Age


Fundamental Movement Skills - Results
Locomotor Skills
Comparisons across Gender and Age
Age
Male
Female


Fundamental Movement Skills - Results
Balance Skills
Comparisons across Gender and Age
Age
Male
Female


Fundamental Movement Skills - Results
Object Control Skills
Comparisons across Gender and Age
Male
Female
Age
DCU


How do individual skills compare?
DCU


Phases of Skill Development from Infancy
Why do we do Physical Activity?
DCU

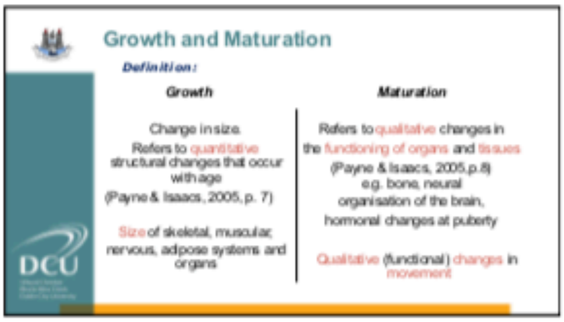

Specialised Movement Phase
Link between FMS and Specialized Movements
Overhand throwing
DCU


Specialised Movement Phase
Mature FMS that has been refined and combined to form sport skills and others complex skills.
Combinations and variations of FMS contribute to body management when performing complex skills.
Specialised movements are task specific, FMS are not.
From 7 – 14+ years old
DCU

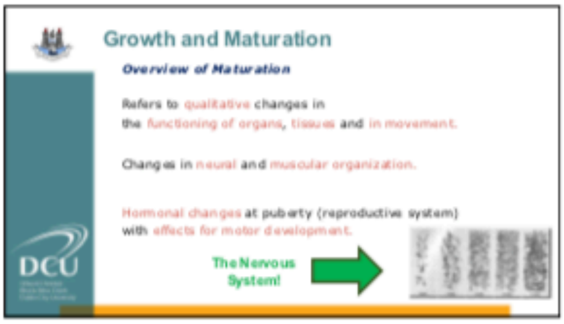

Specialised Movement Phase
Transition Stage 7-10 Yrs
Lead up activities/games and mini sports
More ready for team play towards end of the stage
For a global development:
Wide range of sports & activities recommended
DCU


Skill Development
Fundamental to Sport Specific Skills
Hurling – Overhead Catch
Run
Jump
Coordination
Catch
Land
Run
Strike
DCU


Growth and Maturation
DCU


Growth and Maturation
Definition:
Growth
Change in size.
Refers to quantitative structural changes that occur with age
(Payne & Isaacs, 2005, p. 7)
Size of skeletal, muscular, nervous, adipose systems and organs
Maturation
Refers to qualitative changes in the functioning of organs and tissues
(Payne & Isaacs, 2005, p.8)
e.g. bone, neural organisation of the brain, hormonal changes at puberty
Qualitative (functional) changes in movement
DCU


Growth and Maturation
Examples of Physical Growth
- Refers to quantitative changes
Change in size of head, trunk and limbs
Changes in height/length and width
- Follows a predictable universal pattern
- Individual differences in rate of growth
- Changes in body proportions are uneven (relative growth)
Directional principles of cephalocaudal & proximodistal apply
DCU


Growth and Maturation
Overview of Maturation
Refers to qualitative changes in the functioning of organs, tissues and in movement.
Changes in neural and muscular organization.
Hormonal changes at puberty (reproductive system) with effects for motor development.
The Nervous System!
DCU

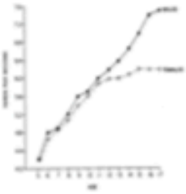

Growth and Maturation
Effects in infancy and childhood
In general growth and maturation facilitate/afford the acquisition and performance of :
- Rudimentary skills in infancy
- Fundamental skills in early childhood
- Specialised skills later childhood and adolescence
DCU

Growth and Maturation

Effects in Adolescence

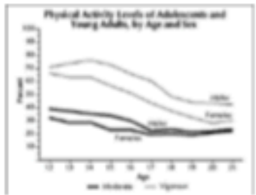
Age related changes in running speed

(Haubenstricker & Seefeldt,1985)



- Between gender differences in timing of growth spurt
- Girls earlier
- Boys larger gains in muscle, strength and power

What implications might this have for sport participation?



Growth and Maturation

Effects in Adolescence

Late developers can pass out early developers in sport performances especially if they have been developing their skills and the early developers have not

Quantitative outcome assessed i.e. distance, height, speed for throwing, jumping, running, etc ...

AGAIN: ASSESSING QUANTATIVE CHANGES IS NOT ENOUGH!!

Growth and Maturation

Direction of Development

Cephalocaudal: Development occurs from head to toe (Literally head to tail!)

Proximodistal: Development occurs from near to far

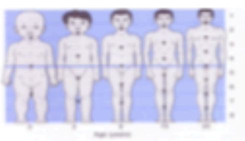
Cephalocaudal control
- Neck, trunk, legs

Proximodistal control
- Shoulder, elbow, wrist, fingers
- Hip, knee, ankle, toes

Growth and Maturation

Direction of Development

In infancy large head and short legs give high centre of gravity



This along with undeveloped legs makes balance and locomotion very difficult.

With age, body proportions change, centre of gravity lowers, legs develop and balance & locomotion become easier.

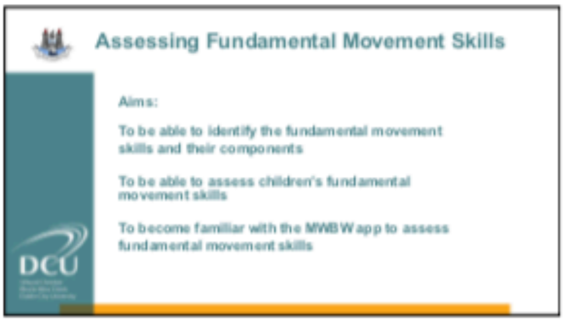
Growth and Maturation

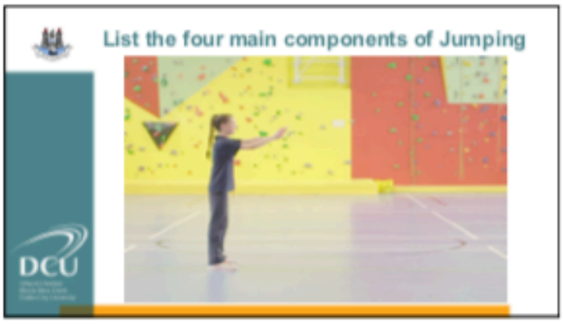
Direction of Development

Proportional changes in size of body parts illustrate cephalocaudal and proximodistal principles


Growth and Maturation
Growth spurt implications for teachers/coaches
Early developers generally at a great advantage
in terms of strength, speed & power.
GOOD PERFORMER
May rely on these aspects rather than develop skill.
Coaches tempted to put them in key positions
in team sports.
Late developers feel discouraged
may give up (stop participating).
DCU


End of Part 1
Lunch Time!!!
Voucher will get you a meal in the main canteen.
Unfortunately it doesn't include dessert!!
Main canteen is directly across from the entrance door to
the left, the glass fronted building.
Meet back here at 2.15pm
DCU

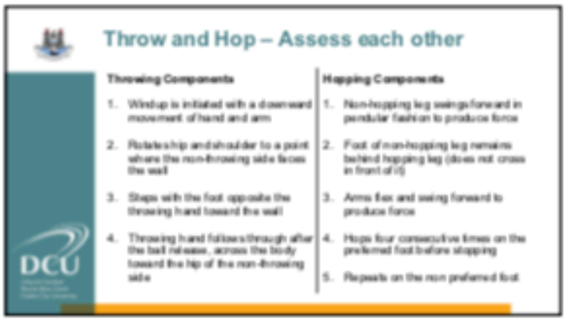

Assessing Fundamental Movement Skills
Aims:
To be able to identify the fundamental movement
skills and their components
To be able to assess children's fundamental
movement skills
To become familiar with the MWBW app to assess
fundamental movement skills
DCU


List the four main components of Jumping
DCU


Components of Jumping
1. Prior to take off both knees
are flexed and arms are
extended behind the back
2. Arms extend forcefully
forward and upward reaching
above the head
3. Both feet come off the floor
together and land together
4. Both arms are forced
downward during landing
DCU


Components of Skipping
1. A step forward followed by a hop on the same foot
2. Arms are flexed and move in opposition to legs to produce force
3. Completes four continuous rhythmical alternating skips
DCU


Components of Kicking
1. Rapid continuous approach to the ball
2. Child takes an elongated stride or leap just prior to ball contact
3. Non-kicking foot placed close to the ball
4. Kicks ball with instep or inside of preferred foot (not the toes)
DCU


Throw and Hop – Assess each other
Throwing Components
1. Windup is initiated with a downward movement of hand and arm
2. Rotates hip and shoulder to a point where the non-throwing side faces the wall
3. Steps with the foot opposite the throwing hand toward the wall
4. Throwing hand follows through after the ball release, across the body toward the hip of the non-throwing side
Hopping Components
1. Non-hopping leg swings forward in pendular fashion to produce force
2. Foot of non-hopping leg remains behind hopping leg (does not cross in front of it)
3. Arms flex and swing forward to produce force
4. Hops four consecutive times on the preferred foot before stopping
5. Repeats on the non preferred foot
DCU


Components of Throwing
1. Windup is initiated with a downward movement of hand and arm
2. Rotates hip and shoulder to a point where the non-throwing side faces the wall
3. Steps with the foot opposite the throwing hand toward the wall
4. Throwing hand follows through after the ball release, across the body toward the hip of the non-throwing side
DCU


Components of Hopping
1. Non-hopping leg swings forward in pendular fashion to produce force
2. Foot of non-hopping leg remains behind hopping leg (does not cross in front of)
3. Arms flex and swing forward to produce force
4. Hops four consecutive times on the preferred foot before stopping
Note: Can be repeated on other foot
DCU

MWBW App Overview

App was developed to eliminate pen and paper method

App stores data and uploads to database in DCU, and eliminates need to transfer data from paper to database

No need for WiFi

Fully GDPR compliant

Day 1 Review

Time	Activity
9:30am	Introduction to the Moving Well-Being Well project
10:00am	Physical Literacy Introduction – Coaching Ireland Certified
10:30 am	**Coffee Break**
10:45am	Motor Control/Motor Development with Practical 1 & 2
1:30pm	**Lunch**
2:15pm	Assessing Fundamental Movement Skills (Practical 4 & 5)
4:00pm	Introduction to the MWBW Assessment App
4:30pm	**Finish**

Start tomorrow at 9.30am

CPD Timeline

Day 2

Time	Activity
9:30 am	Overview of Self-Determination Theory
10:00am	Intervention Practical – Led by PDST
1:30pm	**Lunch**
2:15pm	Health Related Activities Overview
2:45pm	Classroom Active Learning/Home Activity Support
3:15pm	Intervention Implementation
3:45pm	Assessment of Fundamental Movement Skills
4:30pm	**Finish**

Overview of Self Determination Theory

Motivation is the reason for people's actions, willingness and goals.

Different qualities of motivation

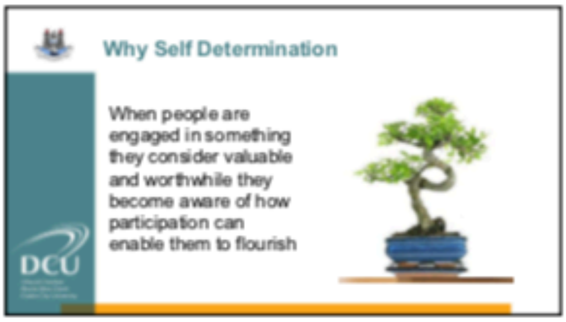
Different qualities are viewed as better forms of motivation: persistence, interest, enjoyment, participation levels

Breakdown of Self Determination Theory

Breakdown of Self Determination Theory
Controlling Motivation
DCU

Breakdown of Self Determination Theory
Autonomous Motivation
DCU

Breakdown of Self Determination Theory
Intrinsic Motivation
Identified Motivation
Introjected Motivation
External Motivation
Sustainable
Dropout
DCU



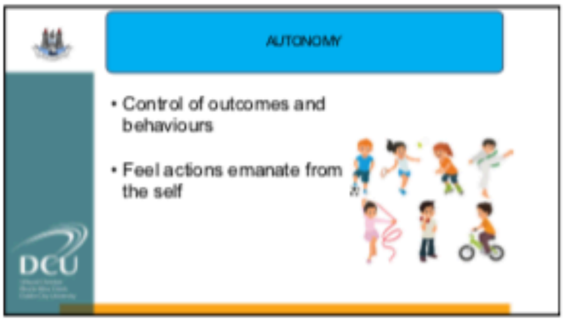
Why Self Determination
When people are engaged in something they consider valuable and worthwhile they become aware of how participation can enable them to flourish
DCU

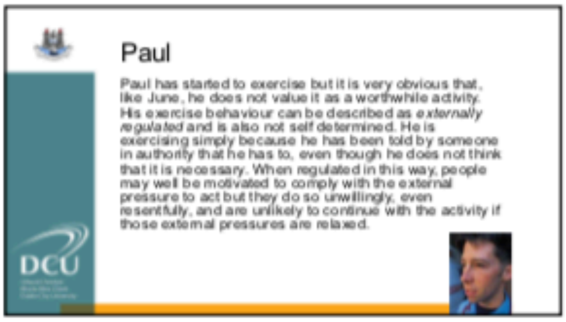
Create Self Determination
Humans have a a need to feel we have some understanding and control
COMPETENCE
AUTONOMY
RELATEDNESS
DCU

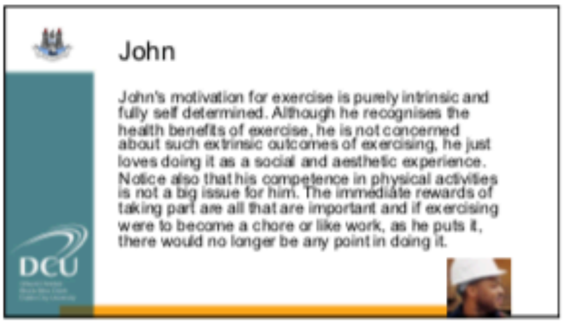
COACHING THE SKILLS
S PACE
T IME/TASK
E QUIPMENT
P EOPLE
I NTRODUCE
D EMONSTRATE
E XECUTE
A TTEND
DCU

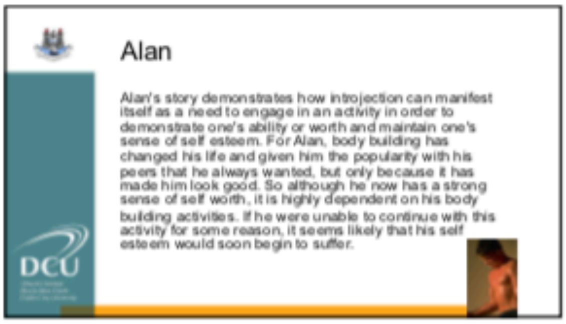

COMPETENCE
• To experience mastery
• To produce desired outcomes
• Personal challenges
DCU


RELATEDNESS
• To feel others relate to oneself
• Care for others
• Feel satisfied and coherent involvement
DCU


AUTONOMY
• Control of outcomes and behaviours
• Feel actions emanate from the self
DCU


Paul
Paul has started to exercise but it is very obvious that, like June, he does not value it as a worthwhile activity. His exercise behaviour can be described as externally regulated and is also not self determined. He is exercising simply because he has been told by someone in authority that he has to, even though he does not think that it is necessary. When regulated in this way, people may well be motivated to comply with the external pressure to act but they do so unwillingly, even resentfully, and are unlikely to continue with the activity if those external pressures are relaxed.
DCU


John
John's motivation for exercise is purely intrinsic and fully self determined. Although he recognises the health benefits of exercise, he is not concerned about such extrinsic outcomes of exercising, he just loves doing it as a social and aesthetic experience. Notice also that his competence in physical activities is not a big issue for him. The immediate rewards of taking part are all that are important and if exercising were to become a chore or like work, as he puts it, there would no longer be any point in doing it.
DCU


Alan
Alan's story demonstrates how introjection can manifest itself as a need to engage in an activity in order to demonstrate one's ability or worth and maintain one's sense of self esteem. For Alan, body building has changed his life and given him the popularity with his peers that he always wanted, but only because it has made him look good. So although he now has a strong sense of self worth, it is highly dependent on his body building activities. If he were unable to continue with this activity for some reason, it seems likely that his self esteem would soon begin to suffer.
DCU

Bill

Bill is not exercising because of externally imposed pressures but because he is putting the pressure on himself. Thus his behavioural regulation is somewhat internalised and can be said to be *introjected*. He acts because of his anxieties about heart disease and an anticipated sense of guilt that if he does become ill he will be letting his young family down. Thus, although he is internally driven, Bill's behaviour is only somewhat self determined.

Liz

Liz's exercise behaviour is less controlled and shows much greater self determination. Her behavioural regulation is *identified*. Identification involves a conscious acceptance of the behaviour as being important in order to achieve personally valued outcomes. The importance of the outcome provides a strong incentive that overrides any difficulties or obstacles to the behaviour. Thus Liz manages to find time to exercise regularly even though she finds it difficult fitting it into her busy work life.

COACHING THE SKILLS

S PACE	**I** NTRODUCE
T IME/TASK	**D** EMONSTRATE
E QUIPMENT	**E** XECUTE
P EOPLE	**A** TTEND

PDST PE - Practical

- Move Well, Move Often Resource

- Training primary school teachers

Incorporating HRA into the lesson

What is HRA?

Health Related Activity

Health-related activities seeks to develop in the student:

- an understanding of the role of health-related activity in the **promotion of wellbeing**.
- an introduction to some of the principles that underpin health-related activity.
- the ability to start to **monitor** their own physical activity level.
- a developing sense of **responsibility** for her/his own good health and wellbeing.

What are the most essential components of HRA for primary school children?

- The **general guidelines associated with regular Physical Activity for health** – 60mins of moderate to vigorous physical activity every day.
- The 'feeling' of moderate-vigorous intensity
- **The benefits of physical activity.**

What are the most essential components of HRA for primary school children?

- Students learn about **different intensities of physical activity** and its effect on the body through **heart rate and breathing rate.**

- Students experience a **variety of choice in the physical activity environment.**

- Students **self-efficacy and attitude towards physical activity** will be emphasised and improved.

Activity and Heart Rate

- During each heartbeat, the muscles of the heart contract causing a wave of pressure which forces blood through the arteries.

- This wave of pressure is known as a **pulse.**

- There is one pulsation for each heartbeat.

- The pulse can be felt at various points on the body where the arteries are just under the skin, the two most easily used for PE class are **neck (carotid) and wrist (radial).**

- The normal pulse rate varies with age.

Radial Pulse

Carotid Pulse

How to tell if you are exercising at moderate or vigorous intensity from HR?

- **For moderate intensity physical activity,** a person's target heart rate should be **50 to 70% of his or her maximum heart rate.**

- This maximum rate is based on the person's age. An estimate of a person's maximum age-related heart rate can be obtained by **subtracting the person's age from 220.**

How to tell if you are exercising at moderate-vigorous intensity from HR?

- For example, for a 14-year-old child, the estimated maximum age-related heart rate would be calculated as 220 - 14 years = 206 beats per minute (bpm). The 50% and 70% levels would then be:

- **50% level: 206 x 0.50 = 103 bpm**
- **70% level: 206 x 0.70 = 144 bpm**

- Thus, moderate-intensity physical activity for a 14 year old child will require that the heart rate remains above 103 bpm during physical activity for it to be deemed MVPA.
(Centres for Disease Control)

1st to 2nd Class kids – average age 6- 8 years

What BPM would they need to remain above for activity to be deemed MVPA?

1st class (6 year olds)
- Moderate 107 – 150 bpm
- MVPA 107+ bpm

2nd class (8 year olds)
- Moderate 106 – 149 bpm
- MVPA 106+ bpm

1st class (6 year olds)
- Moderate 107 – 150 bpm
- MVPA 107+ bpm

2nd class (8 year olds)
- Moderate 106 – 149 bpm
- MVPA 106+ bpm

Taking Heart Rate … FILTER!!

- Works great with 5th 6th class….

…But… 1st/2nd class?

- Important they can distinguish intensity… But is HR the best way?

- How else can they tell?

Help the kids to start to get a feel for how hard their bodies are working

Heart rate

Breathing rate

Temperature

Activity and breathing…some facts!

- At rest, a person breathes about 14 to 16 times per minute. After exercise it could increase to over 60 times per minute.
- New babies at rest breathe between 40 and 50 times per minute. By age five it decreases to around 25 times per minute.
- The total surface area of the alveoli (tiny air sacs in the lungs) is the size of a tennis court.
- The lungs are the only organ in the body that can float on water.
- The lungs produce a detergent-like substance which reduces the surface tension of the fluid lining, allowing air in.

Rate of Perceived Exertion

- The Borg Rating of Perceived Exertion (RPE) is a way of measuring physical activity intensity level.
- Perceived exertion is how hard you feel like your body is working.
- It is based on the physical sensations a person experiences during physical activity, including heart rate, breathing rate, and body temperature.

Again … FILTER!!

1st and 2nd class kids too young for these detailed facts… we need to know them so we can teach/coach effectively, but kids just need to start to understand how their breathing is affected by physical activity!

Activity and Breathing Rate

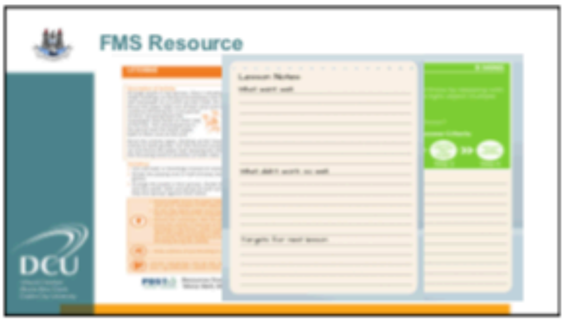
- Get children to place their hand flat against their chest
- Get the children to count how many breaths they take in a minute.
- Do a fun active warm-up and count again.
- Prompt the kids to ascertain if
  - They could feel that their lungs were breathing faster
  - They have any idea why!
- The same idea goes for Heart rate – they will be able to feel their hearts pumping against their chest when they exercise hard – help them to interpret this

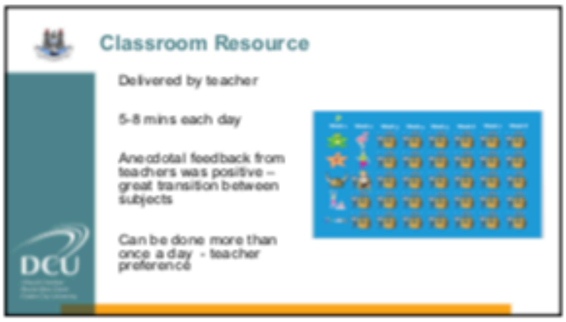
'Fun' Borg Scale!

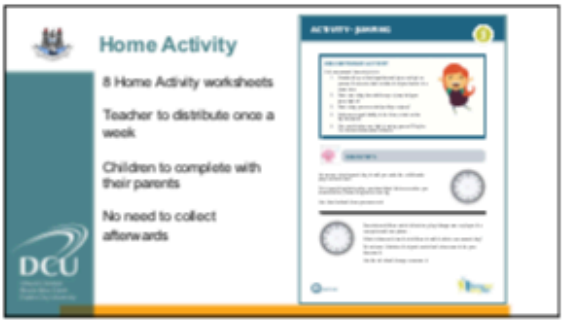
Simply encourage attention to breath, heart and temperature

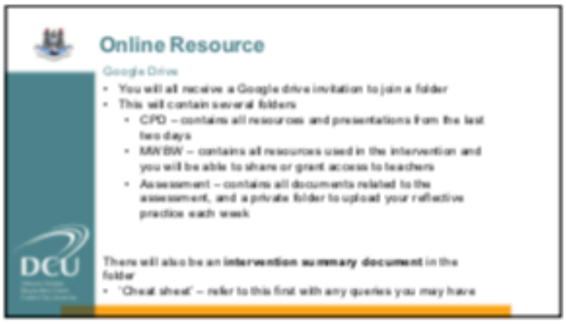

How it all works….
Intervention design
Intervention components
Online Resources
Intervention Implementation
Assessment
interventions
evidence-based
Assessment
DCU


How it all works….
30 minute FMS based class led by coach
Teacher repeats the same class
Coach upskills teacher on the job
Active learning in classroom
5 minutes every day
Skills and activity complexity gradually increases
Home activity once a week
Worksheet to be completed with parent/guardian
Activity and knowledge components
DCU


FMS Resource
Lesson Notes
What went well
What didn't work so well
Targets for next lesson
DCU


Classroom Resource
Delivered by teacher
5-8 mins each day
Anecdotal feedback from teachers was positive – great transition between subjects
Can be done more than once a day - teacher preference
DCU


Home Activity
8 Home Activity worksheets
Teacher to distribute once a week
Children to complete with their parents
No need to collect afterwards
DCU


Online Resource
Google Drive
You will all receive a Google drive invitation to join a folder
This will contain several folders
CPD – contains all resources and presentations from the last two days
MWBW – contains all resources used in the intervention and you will be able to share or grant access to teachers
Assessment – contains all documents related to the assessment, and a private folder to upload your reflective practice each week
There will also be an intervention summary document in the folder
'Cheat sheet' – refer to this first with any queries you may have
DCU