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## **An Investigation into te Relationship Between Fundamental Movement Skill Proficiency and Markers of Health Among a Cohort of Irish Primary School Children**

Linda Bolger  
*Cork Institute of Technology*

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**An Investigation into the Relationship between  
Fundamental Movement Skill Proficiency and  
Markers of Health among a Cohort of Irish Primary  
School Children**

**PART I: THESIS**

Linda Bolger

Department of Sport, Leisure and Childhood Studies

A thesis submitted to Cork Institute of Technology in fulfilment of the requirement for  
the award of Doctor of Philosophy

Candidate Supervisors: Dr. Con Burns, Dr. Cian O' Neill and Dr. Edward Coughlan

Submitted to Cork Institute of Technology, March, 2018

## Abstract

### AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN FUNDAMENTAL MOVEMENT SKILL PROFICIENCY AND MARKERS OF HEALTH AMONG A COHORT OF IRISH PRIMARY SCHOOL CHILDREN

Linda Bolger

**Background:** Fundamental movement skills (FMS) are basic observable patterns of movement. Although FMS are positively associated with health, FMS levels among children worldwide are low. Interventions to improve FMS and markers of health among children are warranted. Thus, the purpose of this research was to firstly evaluate the FMS proficiency and markers of health of Irish primary school children, and to design and implement a programme of interventions to improve both. **Methods:** Two interventions (1 Physical Activity [PA] and 1 FMS) were implemented and evaluated using children from 3 primary schools in Cork. Children (N=217, mean age: 7.98±2.00 years) from senior infants (n=107, mean age: 6.00±0.40 years) and 4<sup>th</sup> class (n=110, mean age: 9.91±0.40 years) participated in the PA intervention evaluation. Children (N=466, mean age: 8.54±2.09 years) from senior infants and 1<sup>st</sup> class (n=222, mean age: 6.45±0.62 years), and 4<sup>th</sup> and 5<sup>th</sup> class (n=244, mean age: 10.44±0.59 years) participated in the FMS intervention evaluation. The Test of Gross Motor Development-2 was used to measure FMS proficiency. Other measures recorded were: height, mass, waist circumference (WC), heart rate (HR), blood pressure (BP), body mass index (BMI) and waist circumference-to-height ratio (WHtR). Cardiorespiratory fitness (CRF) (measured using the 550m run/walk), physical activity (PA) (measured via accelerometry) and perceived FMS competence (measured using the Pictorial Scale of Perceived Movement Skill Competence) were also recorded. Correlation and regression analyses were used to investigate the relationship between FMS and markers of health (BMI percentile, WC percentile, HR, BP percentile, 550m time SDS and PA). Repeated measures ANOVAs and ANCOVAs were used to examine the effectiveness of the two interventions on FMS and markers of health. **Results:** Although there were no significant relationships revealed between FMS and BMI, heart rate and BP, significant positive relationships were found with CRF (6 and 10 year olds respectively:  $r=.286$  and  $r=.330$ ;  $p<0.01$ ) and PA levels across the whole cohort (light and total:  $r=.413$  and  $r=.351$   $p<0.05$ ). After adjusting for age and sex, FMS explained 15.9% and 20.5% of the variance in CRF among 6 and 10 year olds respectively, and 9.7% and 14.4% of the variance in light and total PA across the whole cohort. Results revealed that a 6-month specialist-led PA intervention, that involved two 25-minute PA sessions per week and the encouragement of 20 minutes daily MVPA during class time, had no significant impact on children's FMS. There were positive intervention effects for WC SDS among 6 ( $p<0.01$ ,  $\eta_p^2=0.298$ , large effect size) and 10 year olds ( $p<0.01$ ,  $\eta_p^2=0.061$ , medium effect size). There were also positive intervention effects for WC ( $p<0.01$ ,  $\eta_p^2=0.280$ , large effect size) and WHtR ( $p<0.01$ ,  $\eta_p^2=0.288$ , large effect size) among 6 year olds, and 550m time SDS ( $p<0.01$ ,  $\eta_p^2=0.115$ , medium effect size) among 10 year olds. A tailored, specialist-led 26-week multicomponent FMS-based intervention consisting of FMS-based sessions, the distribution of FMS promotional material, teacher training and PA initiatives, positively affected the FMS of 6 ( $p<0.01$ ,  $\eta_p^2=0.454$ , large effect size) and 10 year olds ( $p<0.01$ ,  $\eta_p^2=0.446$ , large effect size). There were positive intervention effects for BMI ( $p<0.05$ ,  $\eta_p^2=0.045$ , small effect size) and BMI SDS ( $p<0.05$ ,  $\eta_p^2=0.073$ , medium effect size) among 6 year olds and BMI SDS ( $p<0.05$ ,  $\eta_p^2=0.026$ , small effect size), HR ( $p<0.01$ ,  $\eta_p^2=0.050$ , small effect size) and 550m time SDS ( $p<0.05$ ,  $\eta_p^2=0.045$ , small effect size) among 10 year olds. **Conclusion:** While a generic PA intervention had favourable effects on children's adiposity levels, it failed to positively impact on FMS. However, a specifically designed FMS-based intervention was subsequently effective at improving FMS while concurrently reducing adiposity and enhancing CRF. Thus, FMS-based interventions should be implemented in Irish primary schools to improve both FMS and health.

## **Declaration**

I hereby declare that the work contained within this thesis is entirely my own work other than the counsel of my supervisors, Dr. Con Burns, Dr. Cian O' Neill and Dr. Ed Coughlan of the Department of Sport, Leisure & Childhood Studies, Cork Institute of Technology. This work has not been submitted for any academic award, or part thereof, at this or any other educational establishment. Where the use has been made of the work of other people, it has been fully acknowledged and referenced.

### **Candidate:**

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Linda Bolger

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Date

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# Table of Contents

## **PART I: Thesis**

Abstract	ii
Declaration	iii
Acknowledgments	iv
Table of Contents	v
List of Tables	xiii
List of Figures	xi
List of Abbreviations	xii

## **CHAPTER 1: Introduction**

1.1	Introduction	2
1.2	Aim and Hypotheses	6
1.3	Significance of the Research	7
1.3.1	Project Spraoi	8
1.4	Overview of Thesis	11

## **CHAPTER 2: Literature Review**

2.1	Introduction	15
2.2	Fundamental Movement Skills (FMS)	15
2.3	Markers of Health	34
2.3.1	Overweight and Obesity	34
2.3.2	Blood Pressure (BP)	47
2.3.3	Cardiorespiratory Fitness (CRF)	52
2.3.4	Physical Activity (PA)	61
2.4	Perceived Competence (PC)	76
2.5	School-Based Interventions	88

## **CHAPTER 3: Methods**

3.1	Introduction	106
3.2	Participants	107
3.3	Measures Collected	109
3.3.1	FMS Measurement	109
3.3.2	Physical Measures	111
3.3.3	Perceived FMS Competence Measurement	116
3.4	PA Intervention (2014/2015)	117
3.5	FMS-Based Intervention (2015/2016)	121
3.6	Process Evaluation	129
3.7	Statistical Analysis	131

#### **CHAPTER 4: The Relationship between Fundamental Movement Skills and Markers of Health among a Cohort of Irish Primary School Children**

4.1	Abstract	134
4.2	Introduction	135
4.3	Methods	137
4.4	Results	140
4.5	Discussion	145
4.6	Conclusion	152

#### **CHAPTER 5: The Effectiveness of a Physical Activity Intervention on the Fundamental Movement Skill Proficiency and Markers of Health among a Cohort of Irish Primary School Children**

5.1	Abstract	155
5.2	Introduction	156
5.3	Methods	159
5.4	Results	165
5.5	Discussion	175
5.6	Conclusion	178

#### **CHAPTER 6: The Effectiveness of a Tailored Motor Skill Intervention on the Fundamental Movement Skill Proficiency and Markers of Health among a Cohort of Irish Primary School Children**

6.1	Abstract	181
6.2	Introduction	182
6.3	Methods	184
6.4	Results	189
6.5	Discussion	203
6.6	Conclusion	212

#### **CHAPTER 7: Discussion, Conclusion and Recommendations for Future Research**

7.1	Introduction	214
7.2	FMS and Markers of Health	214
7.3	The PA Intervention	216
7.4	The FMS Intervention	217
7.4.1	Practical Implications	220
7.5	Limitations	224
7.6	Conclusion	227
7.7	Recommendations for Future Research	227

<b>Reference List</b>	<b>231</b>
-----------------------	------------

## **PART II: Publications & Appendices (CD-ROM)**

<b>Appendix A: Publications</b>		A1
A.1	Published Paper: <i>Age and Sex Differences in Fundamental Movement Skills among a Cohort of Irish School Children</i>	A2
A.2	Conference Papers	A97
A.3	Conference Poster	A105
<b>Appendix B: Interactive FMS Tool (CD-ROM)</b>		
<b>Appendix C: PA Intervention Material</b>		A82
C.1	Huff and Puff Activity Manual	A83
C.2	Stride for 5 Poster (Diagram and Image)	A135
C.3	Sample Health-Promoting Fridge Magnet (Image)	A136
<b>Appendix D: FMS-Based Material</b>		A137
D.1	Sample FMS-Based Lesson Plan	A138
D.2	Sample FMS posters (The Leap)	A139
D.3	FMS Homework Manuals	A141
D.4	FMS Teacher Manual	A196
D.5	Sample FMS Activity Break Charts	A223
D.6	Certificate Awarded to the Most Active Class	A225
D.7	Homework Pass Voucher	A226
D.8	Kilometre Challenge Score Card	A227
D.9	PE Student of the Week Poster and Certificate	A228
<b>Appendix E: School and Parent Correspondence</b>		A229
E.1	Memorandum of Understanding (MoU)	A230
E.2	Needs Analysis Teacher Questionnaire	A236
E.3	Consent Forms	A238
E.4	Accelerometer Information Sheet	A242
<b>Appendix F: Process Evaluation Material</b>		A243
F.1	Process Evaluation Teacher Questionnaires	A244
F.2	Write and Draw Activity Sheet	A250



## List of Tables

### CHAPTER 2: Literature Review

Table 2.1	Comparison of the features of the TGMD-2 and TGMD-3	26
Table 2.2	Prevalence of overweight/obesity reported from national samples of Irish children (all derived from objectively measured height and mass measurements and using IOTF BMI cut-points)	42
Table 2.3	PA cut-points for children	66

### CHAPTER 3: Methods

Table 3.1	Demographic information of children who provided data pre-and-post PA intervention (2014/2015)	108
Table 3.2	Demographic information of children who provided data pre-and-post FMS intervention (2014/2015)	108
Table 3.3	60-second epoch equivalents of Evenson et al's (2008) cut-points that were used for PA intensity classification	116
Table 3.4	A summary of the PA intervention content	120
Table 3.5	An outline of how the socio-ecological model's framework guided the interventions	122
Table 3.6	A summary of the FMS intervention content	124

### CHAPTER 4: The Relationship between Fundamental Movement Skills and Markers of Health among a Cohort of Irish Primary School Children

Table 4.1	Descriptive data of the children who participated in the study	141
Table 4.2	Descriptive statistics (mean $\pm$ SD) for the PA data collected from a subsample (n=70, 45.7% 6 year olds) of the children who participated in the study	141
Table 4.3	Correlations between FMS variables (locomotor standard score, object-control standard score and gross motor quotient scores) and physical measurements for 6 year olds	142
Table 4.4	Correlations between FMS variables (locomotor standard score, object-control standard score and gross motor quotient scores) and physical measurements for 10 year olds	142

Table 4.5	Correlations between FMS variables (locomotor standard score, object-control standard score and gross motor quotient scores) and PA	143
Table 4.6	Stepwise multiple linear regression analysis explaining variance in 550m time SDS for 6 year olds and 10 year olds	144
Table 4.7	Stepwise multiple linear regression analysis explaining variance in light and total PA	145

**CHAPTER 5: The Effectiveness of a Physical Activity Intervention on the Fundamental Movement Skill Proficiency and Markers of Health among a Cohort of Irish Primary School Children**

Table 5.1	Project Spraoi and the socio-ecological model for health	158
Table 5.2	Effect size classification (Cohen, 1969)	164
Table 5.3	Sex, age and group information of children who participated in the study	165
Table 5.4	Pre- and post-intervention data for 6 year olds from the intervention and control groups	167
Table 5.5	Pre- and post-intervention data for 10 year olds from the intervention and control groups	168
Table 5.6	Pre- and post-intervention PA data for the intervention and control groups	169
Table 5.7	The proportion of 'overweight/obese' children in the intervention and control groups pre- and post-intervention	171
Table 5.8	The proportion of 'centrally obese' children in the intervention and control groups pre- and post-intervention	171
Table 5.9	The proportion of children with 'high-normal/high' BP in the intervention and control groups pre- and post-intervention	171
Table 5.10	The proportion of 'sufficiently active' children in the intervention and control groups pre- and post-intervention	174

## **CHAPTER 6: The Effectiveness of a Tailored Motor Skill Intervention on the Fundamental Movement Skill Proficiency and Markers of Health among a Cohort of Irish Primary School Children**

Table 6.1	Information relating to the children who participated in the study	189
Table 6.2	Pre- and post-FMS intervention data for 6 year olds from the intervention and control groups	191
Table 6.3	Pre- and post-FMS intervention data for 10 year olds from the intervention and control groups	192
Table 6.4	Pre- and post-FMS intervention PA data for the intervention and control groups	193
Table 6.5	The proportion of 'sufficiently active' children in the intervention and control groups pre- and post-intervention	196
Table 6.6	The proportion of children with 'high-normal/high' BP in the intervention and control groups pre- and post-intervention	196
Table 6.7	Teacher responses to the mid-programme questionnaire (N=24)	199
Table 6.8	A summary of positive elements of the intervention identified by teachers	200
Table 6.9	Teacher responses to the end of year questionnaire Likert statements (N=22)	201
Table 6.10	Teacher responses to the end of year questionnaire questions relating to the delivery of the intervention (N=22)	201
Table 6.11	Average daylight hours and temperature during PA data collection	206

## List of Figures

### CHAPTER 2: Literature Review

Figure 2.1	Gallahue and Ozmun's hourglass model of the stages of motor development	16
Figure 2.2	The Canadian Agility and Movement Skill Assessment (CAMSA) course	21
Figure 2.3	A dual energy X-ray absorptiometry (DXA) scanner	37
Figure 2.4	Images from the Pictorial Scale of Perceived Movement Skill Competence used to assess children's perceived competence in the throw	78
Figure 2.5	The relationship between motor competence and health-related variables	82

### CHAPTER 3: Methods

Figure 3.1	FMS testing layout	111
Figure 3.2	550m run/walk test setup	114

### CHAPTER 5: The Effectiveness of a Physical Activity Intervention on the Fundamental Movement Skill Proficiency and Markers of Health among a Cohort of Irish Primary School Children

Figure 5.1	The socio-ecological model for health	158
Figure 5.2	The proportion of 6 and 10 year old children from the intervention and control groups with 'above average' 550m run times pre- and post-intervention	172

### CHAPTER 6: The Effectiveness of a Tailored Motor Skill Intervention on the Fundamental Movement Skill Proficiency and Markers of Health among a Cohort of Irish Primary School Children

Figure 6.1	The proportion of overweight/obese children in the 6 and 10 year old intervention and control groups pre- and post-intervention	194
Figure 6.2	The proportion of children in the 6 and 10 year old intervention and control groups who complete the 550m run/walk in an 'above average' time	197

## List of Abbreviations

<b>FMS</b>	Fundamental movement skills
<b>LOCO</b>	Locomotor
<b>OC</b>	Object-control
<b>PA</b>	Physical activity
<b>MVPA</b>	Moderate-to-vigorous PA
<b>CRF</b>	Cardiorespiratory fitness
<b>BMI</b>	Body mass index
<b>WC</b>	Waist circumference
<b>SDS</b>	Standard deviation score
<b>BP</b>	Blood pressure
<b>SBP</b>	Systolic blood pressure
<b>DBP</b>	Diastolic blood pressure
<b>WHtR</b>	Waist circumference-to-height ratio

# **Chapter 1:**

## **Introduction**

## 1.1 Introduction

Fundamental movement skills (FMS) are basic observable patterns of movement that facilitate participation in physical activity (PA) and sport (Gallahue & Ozmun, 2006). FMS are the foundation upon which more complex, sport-specific skills are based and have been referred to as the 'ABCs of movement' (Robinson, 2011). FMS are categorised into three subcategories: locomotor, object-control and stability skills (Gallahue & Ozmun, 2006). Locomotor skills are those that involve moving the body from one place to another (e.g. running, jumping and leaping) while object-control skills are those that involve the manipulation of an object such as a bat or a ball (e.g. catching, throwing and striking). Stability skills are movements that are neither locomotive nor manipulative (e.g. balancing and twisting) (Gallahue, Ozmun, & Goodway, 2012). Although four studies to date have examined the FMS levels of Irish primary school children (Breslin, Murphy, McKee, Delaney, and Dempster, 2012; Coppinger et al., 2014; Farmer et al., 2017; O'Connor, et al., 2018) one of these was carried out among children from Northern Ireland who received a different PE programme than those in the Republic of Ireland (Breslin et al., 2012); one involved girls only (Farmer et al., 2017) and one involved Gaelic games players only (O'Connor et al., 2018). Breslin et al. (2012) who evaluated the FMS level of a cohort of children from Northern Ireland, examined the FMS level difference between 7-8 year old children who were taught by teachers trained in an FMS programme and those who were not. However, as previously children in Northern Ireland receive a different PE programme than those in the Republic of Ireland and so the generalisability of the results to the Republic of Ireland based population of children is not possible. Furthermore, only a limited amount of information relating to the FMS testing tool and scoring protocol used in their study was provided. In total, 10 FMS were assessed using an adapted tool from 2 previously established FMS assessment tools, the Test of Motor Proficiency (Bruininks, 1978) and the Movement Assessment Battery for Children (Henderson & Sugden, 1992). While the 10 skills assessed were listed, the assessment tool from which each of the skills were taken from was not reported. For instance, the skill of balancing on one foot is included in both the Test of Motor Proficiency and the Movement Assessment Battery. However, it is not outlined which assessment tool was used to measure children's proficiency in this skill. Furthermore, while skill scores were reported, no skill score ranges were provided and so it was not

possible to determine what level of proficiency the children demonstrated. A study conducted by Coppinger et al. (2014) evaluated the FMS proficiency of 122 Irish primary school children (3<sup>rd</sup> and 5<sup>th</sup> class children) using the TGMD-2 and found that less than 1% of children demonstrated 'above average' FMS while 9% demonstrated 'average' FMS. Furthermore, the study revealed that 7%, 50% and 33% of children demonstrated 'below average', 'poor' and 'very poor' FMS, respectively. The study by Farmer et al. (2017) which was carried out among 2<sup>nd</sup> to 6<sup>th</sup> class (8-13 years) primary school girls (N=160), found that Irish primary school girls' FMS levels were low with only three girls (1.9%) demonstrating correct performance of all skill components for the 7 skills (3 locomotor, 3 object-control and 1 stability) assessed. O'Connor et al. (2018) who assessed 13 FMS using the Test of Gross Motor Development-3 (Ulrich, 2013) among 63 'juvenile' Gaelic games players (mean age: 9.9 ± 1.3 years), reported that the proportion of children demonstrating correct performance of a skill exceed 75% for 8/13 skills assessed. However, it should be noted that the sample was small in size (N=63) and as previously outlined, consisted of Gaelic games players only, which may limited the generalisability of the results. Research conducted among Irish post-primary school children revealed poor competency levels in basic movement skills among 12-16 year olds (O'Brien, Belton, & Issartel, 2016; Lester et al., 2017). Given the strong positive relationship that exists between FMS and PA (Fisher et al., 2005; Robinson et al., 2015), the development of FMS has the potential to improve PA levels in children in addition to developing their health-related fitness and perceived competence, whilst decreasing the prevalence of overweight and obesity (Robinson et al., 2015; Stodden et al., 2008).

Overweight and obesity is a worldwide concern and has substantial health and economic repercussions (GBD 2015 Obesity Collaborators, 2017; James & McPherson, 2017; NCD Risk Factor Collaboration, 2016; Wang, McPhearson, Marsh, Gortmaker, & Brown, 2011). Overweight and obesity is associated with numerous adverse health conditions such as breathing difficulties, cardiovascular disease, type 2 diabetes, hypertension, heart disease and some forms of cancers (Krzyzaniak, Kacamarek, Stawinska-Witoszynska, & Krzywinska-Wiewiorowska, 2011; Kurth et al., 2002; Lauby-Secretan, Scoccianti, Loomis, & Grosse, 2016; Lobstein, Baur, & Uauy, 2004; Renehan, Tyson, Eeger, Heller, & Zwahlen, 2008; Singh et al., 2013; Strazzullo et al., 2010). It is also



associated with psychosocial issues with overweight and obese individuals more likely to be teased, bullied, endure social isolation and have low self-esteem compared to their normal weight counterparts (Griffiths, Parsons, & Hill, 2010; R. S. Strauss & Pollack, 2003; van Geel, Vedder, & Tanilon, 2014). Overweight and obesity have major economic repercussions. The global cost of obesity has been estimated at \$2 trillion (Dobbs et al., 2014). Reports suggest that costs associated with overweight and obesity account for 4-7% of total health care costs in the USA (Wang et al., 2011) with similar values reported in Europe (European Commission, 2014). It has been reported that costs attributable to overweight and obesity exceed €60 billion each year in some EU countries (Effertz, Engel, Verheyen & Linder, 2016; European Commission, 2014), with the annual direct healthcare costs attributable to childhood overweight and obesity in Ireland alone estimated at €1.7 million (Perry et al., 2017). A systematic review of the lifetime costs of overweight and obesity in childhood and adolescence which included 13 studies (from both Europe and the USA) found that the mean total lifetime cost of an obese boy (child or adolescent) was €149,206 and that of a girl (child or adolescent) was €148,196 (Hamilton, Dee & Perry, 2018). The mean total lifetime cost of an overweight boy was €57,713. None of the studies included in the review contained data relating to the indirect costs attributable to overweight for girls and so no mean total lifetime cost of an overweight girl was calculated. Reports highlight the extent of the overweight and obesity issue with diseases previously believed to be present exclusively among adults now observed among children (Ebbeling, Pawlak, & Ludwig, 2002; Sahoo et al., 2015; Wiegand, Dannemann, Krude, & Gruters, 2005). With the high prevalence of overweight and obesity among children (Bel-Serrat et al., 2017; WHO, 2017a), and the tracking of overweight and obesity from childhood to later life (Evensen, Wilsgaard, Fuberg, & Skeie, 2016; Herman, Craig, Gauvin, & Katzmarzyk, 2009; Serdula et al., 1993; Simmonds, Llewellyn, Owen, & Woolacott, 2016), the increase in childhood obesity is a worrying public health issue (Sahoo et al., 2015). This increase in overweight and obesity has been attributed to an excess consumption of calories (from energy-dense foods) and a decline in energy expenditure (WHO, 2017b). Such declines in energy expenditure have emerged because of reductions in PA, and are largely due to technological advances (WHO, 2017b).

Physical inactivity is the fourth leading risk factor for mortality worldwide, causing over 3 million deaths every year (WHO, 2017c). Despite the multiple health benefits associated with PA (Janssen & LeBlanc, 2010), only a small proportion of children meet the daily recommended levels (Hallal et al., 2012). In Ireland, only 19% of primary school children were found to engage in the recommended 60 minutes of moderate-to-vigorous PA (MVPA) every day, with an even smaller proportion of post-primary school children achieving this level (Woods, Tannehill, Quinlan, Moyna, & Walsh, 2010). It is likely that the low cardiorespiratory fitness (CRF) levels that have been reported among Irish children (Hudson, Collins, & Comiskey, 2015; Woods et al., 2010) are related to these low PA levels. Irish children have reported that a 'lack of competence' is one of the top three reasons for their non-participation in greater levels of sport and PA (Woods et al., 2010). These findings suggest that the development of competence in PA (the most basic type being FMS) will lead to increased PA levels and thus improved health. In support of this, Stodden et al. (2008) proposed that children with higher actual FMS proficiency will also perceive themselves to be more competent than their less competent counterparts and consequently are more likely to continue participation in sport and PA. As this relationship strengthens with age (Stodden et al., 2008), the childhood years are critical for FMS development.

Schools have been identified as key settings for health-promotion interventions given their access to large numbers of children and very often the availability of suitable facilities, equipment and personnel required to deliver the intervention programmes (Hills, Dengel, & Lubans, 2015). While some research suggests that PA interventions among children result in small to negligible effects on PA (Metcalf, Henley and Wilkin, 2012; Mura et al., 2015), others report that school-based PA interventions can have substantial positive effects on children's PA, fitness and motor skills (Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2015; Kriemler et al., 2011). Notably, a recent systematic review (Tompsett, Sanders, Taylor, & Copley, 2017) reported that FMS-based interventions have consistently been found to be effective at improving FMS proficiency, with some physiological, psychological and behavioural benefits also possible.

There is currently a dearth of literature relating to the levels of Irish primary school children's FMS, CRF and PA. Furthermore, there has been no published research relating to school-based PA and/or FMS interventions that have aimed to improve FMS and markers of health among Irish primary school children. Therefore, the overarching aim of the current research was to measure the FMS proficiency of a cohort of primary school children and subsequently design, implement and evaluate a series of school-based interventions to improve their FMS and markers of health.

## **1.2 Aims and Hypotheses**

The aims and hypotheses of the research as follows:

1. To investigate the relationship between FMS and markers of health among a cohort of Irish primary school children

HØ1: There will be no significant relationship between FMS levels and markers of health among Irish primary school children

HA1: There will be a significant relationship between FMS and markers of health among Irish primary school children.

(Based on previous literature, it was hypothesised that there would be a significant relationship between FMS and markers of health among Irish primary school children)

- 
2. To deliver a PA intervention to children in two intervention schools and evaluate its effectiveness on the FMS proficiency and markers of health of a cohort of Irish primary school children

HØ2: There will be no significant difference in FMS proficiency or markers of health among a cohort of Irish primary school children following a 6-month PA intervention

HA2: There will be a significant improvement in the FMS proficiency and/or markers of health among a cohort of Irish primary school children following a 6-month PA intervention.

(Based on previous literature, it was hypothesised that there would be a significant improvement in the FMS proficiency and/or markers of health among a cohort of Irish primary school children following a 6-month PA intervention.)

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3. Design and implement an age-appropriate FMS intervention for primary school children and evaluate its effectiveness on the FMS and markers of health of a cohort of Irish primary school children

HØ3: There will be no significant difference in the FMS proficiency or markers of health among a cohort of Irish primary school children following a specifically tailored 26-week FMS-based intervention

HA3: There will be a significant improvement in the FMS proficiency and/or markers of health among a cohort of Irish primary school children following a specifically tailored 26-week FMS-based intervention

(Based on previous literature, it was hypothesised that there would be a significant improvement in the FMS proficiency and/or markers of health among a cohort of Irish primary school children following a specifically tailored 26-week FMS-based intervention)

### **1.3 Significance of the Research**

Low FMS (Bolger et al., 2017; Farmer, Belton, & O'Brien, 2017; Lester et al., 2017; O'Brien et al., 2016a), CRF (Woods et al., 2010) and PA levels (Woods et al., 2010) have been reported among Irish youth. These reports, in addition to recent predictions that Ireland is on track to become the fattest of 53 nations by 2030 (Webber et al., 2014), highlight that avenues that have the potential to combat such adverse trends warrant further investigation and indeed appropriate support. Although many researchers have

examined the relationship between children's FMS proficiency and markers of health (Burns, Brusseau, Fu, & Hannon, 2017; Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2014; Lubans, Morgan, Cliff, Barnett, & Okely, 2010), the majority of this research has been carried out among Australian and American youth. There is a dearth of research that relates to the (i) FMS proficiency (ii) relationship between FMS and markers of health and (iii) school-based interventions to enhance FMS and markers of health, among Irish children. While there is a limited amount of published data relating to the FMS of Irish adolescents and the effect of a PA intervention on the FMS, BMI and PA of Irish adolescents (O'Brien, Belton, & Assorted, 2016b), no previous research such as this has been conducted among Irish primary school aged children (4-13 years). The current research will not only present findings related to Irish primary school children's FMS proficiency but will also provide an insight into the relationship between FMS and a comprehensive battery of markers of health (CRF, PA of different intensities, body mass index (BMI), waist circumference-to-height ratio (WHtR) and blood pressure (BP)). It will also evaluate the effectiveness of two school-based interventions (one PA intervention and one FMS-based intervention) on Irish children's FMS proficiency and markers of health. Thus, this research has the potential to identify key strategies that can improve the FMS levels and markers of health of Irish primary school children (which would have significant positive consequences on an individual and national level).

### **1.3.1 Project Spraoi**

The current research forms part of a larger research study, Project Spraoi (<http://projectspraoi.cit.ie/>), an Irish primary school-based health promotion intervention that aims to increase the PA levels, improve the nutritional habits and enhance the overall health and well-being of participating children (Coppinger, Lacey, O'Neill, and Burns, 2016) (<http://www.isrctn.com/ISRCTN92611015>). The project began in 2013 and is co-ordinated by a team of researchers (Project Spraoi Research Team) from Cork Institute of Technology who work in partnership with Project Energize collaborators in New Zealand. Since its origin, Project Spraoi has been delivered to 10 primary schools (five urban and five rural) in Cork city and county. The school-based delivery of Project Spraoi is carried out by trained members of the Project Spraoi

Research Team, known as 'Energizers'. Energizers deliver the project to schools by acting as agents of change in the respective settings (rather than being an additional staff member in the school). Energizers work by supporting school staff members to promote PA and healthy eating among the students. Energizers do this in numerous different ways including:

- modelling PA sessions (e.g. sessions that allow for maximum participation of all students, FMS lessons, huff and puff lessons, gymnastics lessons)
- setting up whole-school PA initiative
- providing PA resources (e.g. equipment and games manuals)
- forming links between the school and PA providers in the local community (e.g. with local sports clubs, universities for the use of facilities)
- establishing PA committees
- aiding in the development of PA and healthy eating policies
- providing healthy eating promotional material (e.g. fridge magnets)
- organising healthy eating parent information evenings or simply being available to talk to or answer any questions teachers may have in relation to PA and nutrition

Energizers are teachers and/or sport science, exercise or nutrition graduates. They are also postgraduate (MSc and PhD) researchers in the area of children's PA and/or nutrition. Research carried out by other members of the Project Spraoi Research Team aims to investigate:

- the effectiveness of a PA and nutrition-based intervention among socio-economically disadvantaged schools
- the effectiveness of a PA- and nutrition-based intervention on children's sedentary behaviours
- the process evaluation of Project Spraoi
- the effectiveness of a PA- and nutrition-based intervention on children's nutritional habits

- the evaluation of children FMS proficiency levels (Bolger et al., 2017) and an in-depth analysis of the effectiveness of a primary school-based motor skill intervention on children's FMS proficiency

The research carried out and presented in this thesis adds to this body of research conducted by the Project Spraoi Research Team. While data for the current research were collected by this postgraduate researcher in conjunction with other members of the Project Spraoi Research Team, this postgraduate researcher:

- reviewed the current literature relating to FMS and the selected markers of health
- organised and co-ordinated all data collection sessions (including all FMS testing sessions)
- scored the locomotor FMS videos of all children who completed FMS testing at each of the 4 time points in addition to scoring 10% of the object-control videos at from each time point to confirm that inter-rater reliability was greater than 85% at each time point. The object-control videos were scored by another postgraduate research who was also conducting research in the area of FMS.
- input all data into excel and SPSS
- analysed all data relating to the physical measurements and CRF
- analysed all PA data
- carried out all statistical analysis
- interpreted the results from SPSS
- generated in-depth discussions based on the findings in addition to practical implications and recommendations for future research
- compiled the final written document.

The current research aims to evaluate (i) the effectiveness of a PA intervention on children's' FMS and markers of health (overweight/obesity, heart rate, BP, CRF and PA) and (ii) the effectiveness of a tailored motor skill intervention on children's' FMS and markers of health.

## **1.4 Overview of Thesis**

This thesis is divided into a number of separate sections, each dedicated to providing a greater insight into FMS and markers of health, the relationship between the two, and the effect of two interventions on the FMS and markers of health among Irish primary school children. The thesis reviews and makes reference to evidence from recent and relevant literature. A number of practical implications and recommendations based on the research findings are also provided.

### Chapter 2: Literature Review

This chapter provides a summary of recent and relevant literature relating to children's FMS, markers of health (overweight and obesity, BP, CRF, PA), perceived competence and PA-based interventions among children. A number of key tools and issues that are common in measuring FMS, markers of health and perceived competence are discussed. The current levels of FMS/markers of health/perceived competence among children worldwide and in Ireland are reviewed and the sections dedicated to markers of health and perceived competence also review the relationship between these variables and FMS among children. This chapter also provides an overview of school-based interventions which includes a discussion relating to evidence-based recommendations for PA and health promoting interventions. A number of school-based interventions are also reviewed in terms of their effectiveness on children's FMS proficiency and markers of health. A brief overview of process evaluation and its importance in intervention studies is also provided.

### Chapter 3: Methods

This chapter provides an in-depth review of the methods used to examine the relationship between FMS and markers of health, and to evaluate the effectiveness of two primary school-based interventions. This chapter provides a detailed account of the protocols used in the collection of data (FMS proficiency, physical measures and perceived competence). It also provides an in-depth account of the two interventions that were delivered as part of the research. This account outlines the processes used for school and participant selection and recruitment, as well as the design, content and



delivery of the intervention. The protocols used to collect process evaluation data and the statistical analysis used in the research is also outlined.

#### Chapter 4: The Relationship between Fundamental Movement Skills and Markers of Health among a Cohort of Irish Primary School Children

This chapter presents findings from a cross-sectional study investigating the relationship between children's FMS proficiency (locomotor standard score, object-control standard score and gross motor quotient) and a comprehensive battery of markers of health (BMI percentile, waist circumference (WC) percentile, heart rate, BP percentile, 550m standard deviation score (SDS) and PA). The relationships between the FMS variables and the physical measurements are examined separately for the '6 year old' and '10 year old' cohorts to provide a greater insight into the nature of these relationships based on age. Due to limited accelerometer availability, the relationship between FMS and PA variables are analysed with 6 and 10 year old children grouped together. This study also used regression analysis to estimate the proportion of variance in CRF and PA that can be explained by FMS.

#### Chapter 5: The Effectiveness of a PA Intervention on the Fundamental Movement Skill Proficiency and Markers of Health among a Cohort of Irish Primary School Children

This chapter outlines the PA intervention carried out during the 2014/2015 academic year and reports its effectiveness on children's FMS proficiency and markers of health. The chapter provides a short review of the relationship between FMS and markers of health. It also outlines the protocols used for the collection of data (FMS, markers of health and process evaluation), and presents details relating to the design, delivery and content of the intervention. The chapter also includes an in-depth discussion of the key findings and outlines recommendations for future interventions.

#### Chapter 6: The Effectiveness of a Tailored Motor Skill Intervention on the Fundamental Movement Skill Proficiency and Markers of Health among a Cohort of Irish Primary School Children

This chapter presents the FMS-based intervention delivered during the 2015/2016 academic year and reports on its effectiveness on children's FMS proficiency and markers of health. A short overview of a number of school-based FMS-based

interventions is provided. The methods used to collect and analyse data (FMS, physical measurements, perceived competence and process evaluation) are described and a detailed account of the intervention components is provided. This chapter presents the results of the intervention evaluation and discusses a number of practical implications. The strength and limitations of the study are also reported.

#### Chapter 7: Discussion, Conclusion and Recommendations for Future Research

This chapter provides an overall conclusion for the holistic research process undertaken. Practical implications of the current research and recommendations for future research in this field are also provided. In addition, limitations of the research are outlined. A list of references used in the research and also a number of appendices that contain material used in the research are also included.

## **Chapter 2: Literature Review**

## **2.1 Introduction**

The literature review is divided into four main sections. Section one provides an overview of FMS, how FMS are assessed, the benefits of high FMS proficiency and the current levels of FMS proficiency among youth. Section two reviews a number of selected markers of health that are theorised to be associated with high levels of FMS. Those included in this section include overweight/obesity, CRF and PA. Section three gives details about perceived competence, which has been found to mediate the relationship between FMS and those markers of health referred to in the previous section. Finally, section four gives an outline of interventions that have been carried out among youth to improve FMS and markers of health. The studies reviewed that presented their findings using correlation coefficients, are critiqued and analysed using Zhu's (2012) interpretation of correlation coefficients: no correlation ( $r=0-0.19$ ), low ( $r=0.20-0.39$ ), moderate ( $r=0.40-0.59$ ), moderately high ( $r=0.60-0.79$ ) or high ( $r\geq 0.80$ ).

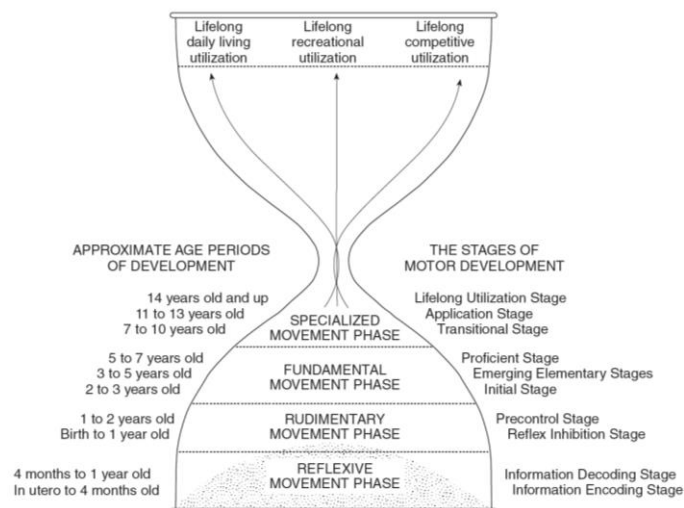
For this purpose of this comprehensive review of the literature, online searches of PubMed and SportDiscus were conducted for studies published after 2000. Keywords used in the search were PA, CRF, overweight, obesity, markers of health, children, fundamental movement skills, perceived competence, interventions, validity and reliability. The titles and abstracts of the articles returned in the search were screened for suitable literature. The inclusion criteria were that the study participants (i) were healthy and (ii) had been measured for at least one of the following: PA, CRF, body composition, fundamental movement skill, perceived competence. The reference lists of the selected papers were also screened for additional relevant articles, with such additional articles sourced and screened for further suitable literature. Relevant unpublished theses were also included in the literature review.

## **2.2 Fundamental Movement Skills (FMS)**

FMS are basic observable patterns of movement upon which more complex, sport specific skills are based (Clark & Metcalf, 2002; Gallahue & Ozmun, 2006; Stodden et al.,

2008). FMS facilitate participation in sporting and physical activities by (i) directly transferring to a sports skill (e.g. the overhand throw transferring to the badminton overhead clear and javelin throw) (O’Keeffe, Harrison, & Smyth, 2007) and (ii) underlying attributes of one skill (e.g. dynamic balance, inter- and intra-muscular coordination, optimal relative time of body segment interactions) transferring to other skills required for sporting/physical activities (e.g. hand-eye coordination developed during catching may facilitate the striking or control of a ball in hockey) (Barnett, Stodden, et al., 2016).

FMS do not develop ‘naturally’ (Stodden et al., 2008), but must be learned, practised and reinforced (Gallahue & Ozmun, 2006; Logan, Robinson, Wilson, & Lucas, 2011; Morgan et al., 2013). The early years (3-7 years) have been highlighted as a critical period during which the development of FMS occur, with children having the potential to be proficient in FMS by the age of 6 years (Gallahue & Ozmun, 2006). Gallahue and Ozmun’s (2006) hourglass model of motor development (Figure 2.1) identifies five major stages of motor development: the reflexive movement phase, the rudimentary phase, the fundamental movement phase, the specialised movement phase and the lifelong utilisation phase. The sequential nature of the model, which outlines that one must pass through the different stages of development in chronological order, reinforces the importance of FMS for participation in lifelong participation in sport and PA.



**Figure 2.1:** Gallahue & Ozmun’s (2006) hourglass model of the stages of motor development

### Measuring FMS

Originally, FMS assessment tools were developed to allow for the identification of children with motor development delays (Barnett, Stodden, et al., 2016; Ulrich, 2000) . However, more recently assessment batteries have been used to (i) classify children based on FMS proficiency level, (ii) tailor PA/physical education programmes to meet the needs of the participants and thus maximise their effectiveness, (iii) evaluate the success of such programmes in terms of FMS development, (iv) provide accurate feedback to children and parents/guardians on their performance of FMS to allow for further development and (v) examine the relationship between FMS proficiency and health (Burton & Miller, 1998; Hands, 2002; Logan, Barnett, Goodway, & Stodden, 2017; Ulrich, 2000).

There is no gold standard for the assessment of FMS and a variety of measurement tools have been developed (Cools, Martelaer, Samaey, & Andries, 2009). Tools may differ in terms of whether they are product or process-oriented, how many skills are assessed, what skills are assessed, testing administration and scoring protocols. Product-oriented tools include the Movement Assessment Battery for Children, 2<sup>nd</sup> edition (MABC-2) (Henderson, Sugden, & Barnett, 2007), the Körperkoordinationstest für Kinder (KTK) (Kiphard & Schilling, 1974; 2007) and the Bruininks-Oseretsky Test of Motor Proficiency-2 (BOT-2) (Bruininks & Bruininks, 2005). Examples of process-oriented tools include the Test of Gross Motor Development (TGMD) (Ulrich, 1985), Test of Gross Motor Development-2 (TGMD-2) (Ulrich, 2000), Test of Gross Motor Development-3 (TGMD-3) (Ulrich, 2013), Get Skilled: Get Active (NSW Department of Education and Training, 2000), the Children's Activity and Movement in Preschool Study Motor Skills Protocol (CHAMPS) (H. G. Williams et al., 2009) and the 'FMS: A Manual for Classroom Teachers' assessment tool (Department of Education Victoria, 1996).

Quality research depends on accurate results, which can only be obtained using reliable and valid assessment instruments. The quality of an assessment tool is evaluated by assessing its psychometric properties, i.e. its reliability and validity (Kimberlin & Winterstein, 2008). There are three types of reliability that can be reported; test-retest reliability, internal consistency and inter-/intra-rater reliability (Thomas, Nelson, &

Silverman, 2011). The test-retest reliability of a measure indicates the stability/reproducibility of the same result from the same individual and testing conditions across more than one time point. Internal consistency measures the degree of reproducibility of the same result from sets of items from the same test. Inter-/intra-rater reliability measures the degree of similarity between the scores of evaluators measured from the same observation and using the same assessment instrument. Reliability coefficients indicate the level of reliability and range from 0 to 1. Higher coefficients indicate higher levels of reliability (Kimberlin & Winterstein, 2008). Reliability coefficients above 0.75 show good reliability, with coefficients greater than 0.9 indicating excellent reliability (Koo & Li, 2016). The validity of a measure refers to the degree of accuracy of the results obtained from the measure. Three types of validity that are widely reported are content, criterion-related and construct validity (Gaberson, 1997). Construct validity involves the examination of the relationship between the measure being evaluated and variables that are either known to be related to or are theoretically related to that measure (M. E. Strauss & Smith, 2009). Content validity, which is typically judged by experts in their respective fields, refers to how well the tool/instrument are at providing an adequate and representative sample of all the items that may measure the variable of interest. Criterion-related validity examines the relationship between a construct evaluated using the new tool/instrument and other measures of the same construct (or similar constructs that theoretically should be related) (Kimberlin & Winterstein, 2008). Validity coefficients rarely exceed 0.40, with coefficients about 0.35 indicating that the tool is very useful (Murphy & Davidshofer, 2005).

Product-oriented FMS tools measure the outcome of the movement being assessed (e.g. the speed, distance, height, number of successful attempts) (Hands, 2002). Product-oriented assessment tools are reliable owing to their objective nature (Spray, 1987), can test large groups over a relatively short period of time and do not require the administrator to have a deep understanding of FMS (Hands & McIntyre, 2015). However, such tools are limited in that they cannot provide information regarding the movement pattern used to produce the measured result (e.g. it cannot be discerned if a slow run time is a result of inefficient arm movement, below optimal stride length, low knee lift

or a combination of these) (Hands, 2002). Furthermore, the accurate interpretation of test results obtained from product-oriented tools requires an appropriate normative sample (similar in height, mass, body composition and cultural expectations) to compare to (Hands & McIntyre, 2015).

Process-oriented FMS assessment tools involve direct observation and are concerned with the technique used to perform the skills. Many process-oriented assessment tools involve the use of predefined performance criteria checklists (based on an expert performance of the skill) in which scores are awarded based on the presence or absence of such criteria across a number of test trials (e.g. a score of 1 is awarded if the criterion is observed and a score of 0 is awarded if is not).

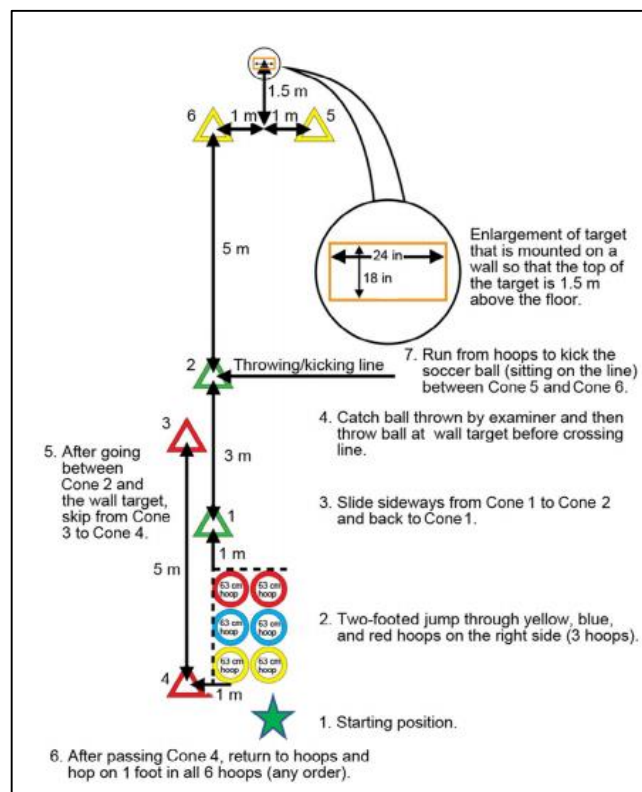
Benefits of the process-oriented tools are that they provide information relating to the pattern of movement used to perform the skill and can identify specific components of a skill that require practice. Process-oriented tools have also been found to be correlated with product-oriented assessments of FMS (Logan et al., 2017; Robertson & Konczak, 2001). However, it should be noted that observations using process-oriented tools are subjective, which often makes it difficult to compare results between assessors. To limit the effect of inter-observer differences on assessment results, training and inter-observer reliability of 85% between assessors is recommended (Thomas et al., 2011). Process-oriented assessments of FMS are much more time consuming than product-oriented assessments as they typically involve the capture of video recordings of skill performances of large groups (which must then be uploaded to a computer), inter-observer reliability and scoring (of multiple components for each skill across multiple trials), while product-oriented assessments typically only involve the measuring and recording of one outcome per skill performance. While process-oriented tools can assess the pattern of movement used to perform a skill by identifying whether specific behavioural components are present during a skill performance or not (e.g. the bending of the knees to lower the body in performing the roll), it has been noted that they may not reflect improvements in certain key factors that allow for improved performance in a given skill such as relative timing, segmental angular velocity and use of the stretch shortening cycle (Stodden, Gao, Goodway, & Langendorfer, 2014; Stodden, Langendorfer, Fleisig, & Andrews, 2006; Stodden & Rudisill, 2006).



Process-oriented tools not only differ from each other in terms of the number of skills assessed, the actual skills that are assessed, the number of components included in the checklists, the skill components that are included in the checklist and whether they are scored live or recorded and scored retrospectively, but also in terms of how mastery (i.e. correct performance of a component/skill) is defined. For instance, to award 'mastery' of a component, the TGMD-2 requires the component to be present in both of the test trials performed during the test, the Get Skilled: Get Active requires it to be present in four out of five trials while the FMS-A Manual for Classroom Teachers (Department of Education Victoria, 1996) only requires it to be present in four out of six trials. Further to this, results are often reported differently from the different tools and studies using terms such as 'mastery', 'near mastery', 'mastery/near-mastery', 'advanced proficiency', 'standard scores', 'age equivalents', 'subset scores' and 'gross motor quotients'. The gross motor quotient (GMQ) is a numeric representation of a child's overall FMS performance. For example, the GMQ for the TGMD-2 is obtained by converting the sum of the locomotor and object-control standard scores to a pre-defined value outlined in the TGMD-2 scoring manual. These pre-defined values were derived based on USA normative data. Essentially the GMQ is an age and sex-specific standard score for overall FMS performance. These differences mean that findings from studies that use different tools or present their findings using different scoring methods cannot be accurately compared.

While both product- and process-oriented tools are useful in gathering information relating to children's FMS performance levels, it is recommended that process-oriented tools are used to assess FMS proficiency among young children, while product-oriented tools may be more appropriate for older children who have mastered most if not all components of the skills (Hands, 2002). A tool that assesses both product and process aspects of FMS (e.g. the Canadian Agility and Movement Skill Assessment) (Longmuir et al., 2015) may be able to provide a greater insight into the FMS level of children than either product- or process-oriented tools alone (Logan et al., 2017). The Canadian Agility and Movement Skill Assessment (CAMSA) involves the completion of seven movement tasks laid out across a 20m course. Tasks to be completed during the test are two-footed jumping into and out of three hoops that are laid on the ground, sliding for three metres,

catching a ball, throwing the ball at a target (that is on the wall five metres away), skipping (for five metres), single-leg hopping into and out of six hoops that are on the ground and kicking a soccer ball between two cones that are a distance of five metres away (Figure 2.2) (Longmuir et al., 2017). Children are provided with two demonstrations; the first a slow demonstration during which each task/skill is explained as it is performed and a second performed showing the required effort and speed. Children are instructed to complete the course as quickly as possible while also performing each task/skill to the best of their ability. Based on the test performance, children are awarded a time-based score and a skill quality score. The time-based score ranges from 1-14 and depends on the time taken to complete the course (the time from the 'Go' signal to the time when the soccer ball is kicked). The skill quality score also ranges from 1-14 and is arrived at using a pre-determined list of 14 skill criteria that were drawn from the TGMD-2. If the skill criterion is present a score of one is awarded. If it is absent, a score of zero is given. These two scores (the time-based score and the skill quality score) are subsequently summed to give a total test score. Total test score, therefore ranges from 2-28, with higher scores indicating higher levels of performance than lower scores.



**Figure 2.2:** The Canadian Agility and Movement Skill Assessment (CAMSA) course

This tool is relatively new and has been found to be reliable and valid among a convenience sample of Australian children (N=1,165) aged between 8 and 12 years (Lander, Morgan, Salmon, Logan, & Barnett, 2017; Longmuir et al., 2015). The results of the study found that the CAMSA test components had moderate to excellent reliability over a one week period with inter-rater reliability (ICC=0.69 for skill score, ICC=0.997 for the measurement of completion time), intra-rater reliability (ICC=0.52 for skill score, ICC=0.996 for completion time) and test-retest reliability (ICC=0.74 for skill score, ICC=0.82 completion time) established. The study also confirmed the convergent validity of the tool (Longmuir et al., 2017) while face validity has also been established (Francis et al., 2016).

The Get Skilled Get Active (GS:GA) instrument is a process-oriented assessment tool consisting of 12 FMS; balance, run, vertical jump, catch, hop, side gallop, skip, overarm throw, leap, kick, 2-handed strike and dodge. While subscale scores are not reported from the test, skills from all three categories of FMS (i.e. locomotor, object-control and stability) are included. Skills consist of 5-7 behavioural components with respective components marked as present if they are observed on 4 or 5 performance trials. A study by Logan et al. (2017) that assessed the standing long jump, hop and overarm throw among 4-11 year olds (N=170) using the GS:GA and TGMD-2 (both of which award scores based on the quality of the technique used to perform the skill) found that the GS:GA scores presented stronger correlations with the product scores of these skills (i.e. the distance jumped, hopped and the distance the object was thrown) than the TGMD-2 scores did. The GS:GA also contained a higher level of sensitivity to identify advanced skill levels (i.e. a lower proportion of children achieving mastery/near mastery) than the TGMD-2 for the hop and throw. It should be noted, however, that an adapted version of the GS:GA protocol (2 trials instead of 5 were performed) and only 3 skills were assessed in the study. Despite being a widely used assessment tool, research relating to the validity and test-retest reliability of the GS:GA is limited (Barnett, van Beurden, Morgan, Lincoln, et al., 2009). Furthermore no normative scores for the GS:GA have been reported (Logan et al., 2017).

The Test of Gross Motor Development-2 (TGMD-2) (Ulrich, 2000), a revision of the original Test of Gross Motor Development (Ulrich, 1985), is a criterion and norm-referenced process-oriented assessment tool. The TGMD-2 assesses 12 FMS; 6 locomotor (run, leap, hop, gallop, slide, horizontal jump) and 6 object-control (catch, overarm throw, underhand roll, kick, 2-handed strike and stationary dribble) skills. The test has been found to be valid and reliable for children aged 3-10 years (Ulrich, 2000). Reliability coefficients (Cronbach's alpha) for the subsets of the TGMD-2 for 3-10 year old children ranged from 0.76 to 0.92, with even higher coefficients (ranging from 0.87-0.94) reported for GMQ scores (Ulrich, 2000).

Test-retest reliability was assessed using scores obtained for 75 USA children (aged 3-10 year old) with a two week period between the two testing dates. The correlation coefficient reported between these scores were high for the locomotor subset ( $r=.88$ ), object-control subset ( $r=.93$ ) and the gross motor quotient ( $r=.96$ ) (Ulrich, 2000). When 30 randomly selected assessments of FMS from the normative sample were scored by independent evaluators, inter-rater reliability was 0.98 for locomotor subset score, object-control subset score and GMQ (Ulrich, 2000).

Content validity of the TGMD-2 was established by three expert judges and also quantitatively using Pearson correlation index (Ulrich, 2000). Criterion validity (more specifically criterion-prediction validity) of the TGMD-2 was examined by assessing the FMS of 41 primary school children from Texas using the TGMD-2 and two weeks later using the Basic Motor Generalizations subtest of the Comprehensive Scales of Student Abilities (CSSA) (Hammill & Hresko, 1994). The calculated partial correlations (that controlled for age) between the subsets of the TGMD-2 and the CSSA were 0.63 for the locomotor subsets and 0.41 for the object-control subsets, indicating acceptable criterion validity for the subsets of the TGMD-2. Construct validity of the TGMD-2 was verified by demonstrating that:

- (i) FMS proficiency measured according to the TGMD-2 is developmental in nature and is strongly correlated with age ( $r$  range: 0.69-0.75)

- (ii) FMS proficiency assessed using the TGMD-2 can distinguish between children known to have different FMS levels (demonstrated by the difference in FMS levels of typically developing children from three ethnic groups and a sample of children with Down Syndrome)
- (iii) the two TGMD-2 subsets measure FMS but in different ways (demonstrated by the moderately sized ( $r=.41$ ) correlation between locomotor and object-control subset scores of the normative sample)
- (iv) the items on the TGMD-2 have acceptable discriminating powers
- (v) the TGMD-2 measures overall (or total) FMS proficiency and can also measure locomotor and object-control proficiency (confirmed by explanatory factor analysis)
- (vi) the skills included in each respective subset are valid indicators of either locomotor or object-control proficiency (as demonstrated using confirmatory factor analysis) (Ulrich, 2000).

The TGMD-2 testing protocol involves the performance of one familiarisation and two test trials, performed following a silent demonstration of the skill. Test trials are typically video recorded and retrospectively analysed using the TGMD-2 scoring protocol (Ulrich, 2000). Each skill consists of 3-5 performance criteria or behavioural components. A score of 1 is awarded if a component is observed as present, while a score of 0 is awarded if it is not. Scores from the TGMD-2 can be presented as skill raw scores, subset raw scores, standard scores (an age- and sex-based conversion of the subset raw scores to a value within a distribution that has a mean of 10 and a standard deviation of 3), age equivalents, percentile scores (which indicate the percentage of the normative sample who scored equal to or below the given score) or Gross Motor Quotients. The Gross Motor Quotient (GMQ) (Ulrich, 2000) has been widely used as an estimate of an individual's motor development (as it is compared to a normative sample of 1,208 children from 10 USA states) and is an indication of both locomotor and object-control skill competency (Burton & Rodgerson, 2001). While the TGMD-2 captures both locomotor and object-control skills, no stability skills are included, which might be viewed as a limitation of the tool. It has also been suggested that the skills included may be inappropriate for cross cultural use, as the skills included relate to American sports

and physical activities (Cools et al., 2009). However, despite these limitations, the test is easy to administer and can evaluate a large number of participants in a relatively short period of time.

The Test of Gross Motor Development-3<sup>rd</sup> edition (TGMD-3) (Ulrich, 2013) is a revision of the TGMD-2 and has also been shown to be a valid and reliable assessment of FMS among children aged 3-10 years (Wagner, Webster, & Ulrich, 2015; Webster & Ulrich, 2017). Additionally, the TGMD-3 has been shown to allow for the valid and reliable assessment of FMS among children with autism spectrum disorder when the TGMD-3 visual support protocol is used (Allen, Bredero, van Damme, Ulrich, & Simon, 2017). The TGMD-3 assesses 13 FMS which are divided into two subcategories; locomotor and ball skills (defined as 'object-control' in the TGMD-2). The administration and scoring protocol of the test is identical to that of the TGMD-2 (i.e. the silent demonstration provided by the test administrator is followed by the performance of one familiarisation and two test trials by the child being tested). As in the TGMD-2, each skill consists of 3-5 performance criteria. The two test trials are used for scoring purposes, with a score of 1 awarded for a present behavioural component and a score of 0 awarded if it is absent. While 10 of the skills included in the TGMD-2 are also in the TGMD-3, some performance criteria have been updated (Table 2.1). TGMD-3 normative data are still currently being collected and have yet to be published.

The reliability and validity of the TGMD-3 was examined among a sample of 807 children (mean age: 6.33 ± 2.09 years). A reliability analysis reported small to moderate correlations with age for locomotor skills ( $r=.39$ ) and ball skills ( $r=.47$ ), with very high internal consistency reported for each age group for all racial/ethnic groups and for both boys and girls. High test-retest reliability was reported for locomotor (ICC=0.97), ball skills (ICC=0.95) and TGMD-3 score (ICC=0.97). In terms of validity, acceptable item difficulty (range=0.43-0.91) and item discrimination (range=0.34-0.67) were found. Acceptable construct validity for the TGMD-3 was found using confirmatory factor analysis (CFI = .95,  $p<0.01$ ) (Webster & Ulrich, 2017).

**Table 2.1:** Comparison of the features of the TGMD-2 and TGMD-3

	<b>TGMD-2</b>	<b>TGMD-3</b>
<b>No. of skills</b>	12	13
<b>Subcategories</b>	<b>Locomotor</b>	<b>Locomotor</b>
	Run	Run,
	Hop	Hop
	Gallop	Gallop
	Horizontal Jump	Horizontal Jump
	Slide	Slide
	Leap	Skip
	<b>Object-Control</b>	<b>Ball Skills</b>
	Catch	2-hand Catch
	Overhand Throw	Overhand Throw
	2-handed Strike	2-handed Strike of a Stationary Ball
	Kick	Kicks a Stationary Ball,
	Stationary Dribble	One Hand Stationary Dribble
	Underhand Roll	Underhand Throw Forehand Strike of a Self-bounced Ball
<b>For use among</b>	3-10 year olds	3-10 year olds
<b>Administration protocol</b>	A silent demonstration provided by test administrator followed by 1 familiarisation and 2 test trials performed by the child	A silent demonstration provided by test administrator followed by 1 familiarisation and 2 test trials performed by the child
<b>Scoring protocol</b>	Skills consist of 3-5 performance criteria.	Skills consist of 3-5 performance criteria.
	A score of 1 is awarded if a criteria is observed; a score of 0 awarded if not.	A score of 1 is awarded if a criteria is observed; a score of 0 awarded if not.
<b>Studies reporting validity and reliability</b>	Ulrich (2000)	Webster & Ulrich (2017)
		TGMD-3 (German version) Wagner et al. (2015)
		Children with autism spectrum disorder (Allen et al., 2017)
<b>Differences in performance criteria of skills in both assessment tools</b>		
<b>Hop</b>	Takes off and lands 3 consecutive times on preferred foot.	Hops 4 consecutive hops on preferred foot before stopping.
	Takes off and lands 3 consecutive times on non-preferred foot.	
<b>Horizontal Jump</b>	Arms extend forcefully forward and upward reaching full extension above the head	Arms extend forcefully forward and upward reaching above the head
<b>Slide</b>	A step sideways with the lead foot followed by a slide of the trailing foot to a point next to the lead foot.	A step sideways with the lead foot followed by a slide with the trailing foot where both feet come off the surface briefly.
<b>2-handed Strike</b>	Non-preferred side of the body faces the imaginary tosser with feet parallel.	Child's non-preferred hip/shoulder points in direction of straight ahead.
	Transfers body weight to front foot.	Step toward ball with non-preferred foot
	Bat contacts ball.	Hits ball sending it straight ahead.
<b>Stationary Dribble</b>	Ball contacts surface in front of or to the outside of foot on preferred side	This component removed.
<b>Kick</b>	Kicks ball with instep of the preferred foot (shoe-laces) or toe	Kicks ball with instep of preferred foot (not the toes).

### Benefits of FMS

Developing FMS has the potential to promote physically active lifestyles in childhood, adolescence and adulthood (Breuer & Wicker, 2009). Stodden et al.'s (2008) conceptual model suggested that the development of FMS is a key factor in their proposed 'spiral of engagement' (along with higher perceived competence, higher PA levels and greater fitness levels) that will promote a healthy weight. Systematic reviews have reported positive associations between FMS and PA, FMS and fitness (Cattuzzo et al., 2016; Lubans, et al., 2010) and a negative relationship between FMS and adiposity level (Lubans et al., 2010). Research has also reported positive associations between FMS and perceived competence (LeGear et al., 2012), academic performance (Haapala, 2013) and enjoyment of PA (Salmon, Ball, Hume, Booth, & Crawford, 2008). A recent study by Sogut (2017) also suggests that FMS proficiency may be associated with elite performance in sport. The study carried out among 11-14 year old tennis players (N=35), found that elite players (those who had competed at national and international level) had significantly higher serve speeds ( $p<0.05$ ) and FMS scores ( $p<0.05$ ) than club level players. However, it should be noted that FMS was measured using the product-oriented Körperkoordinationstest für Kinder (KTK) (Kiphard & Schilling, 2007) in the study and so the higher serve speeds of the elite players relative to their club level counterparts may have been as a result of greater power and speed of the elite level players as opposed to better technique during skill performance. While the research by Sogut (2017) suggests that FMS proficiency may be associated with elite performance, research investigating differences between elite and non-elite sport players using process-oriented FMS assessment tools or a combination of process and product-oriented assessment tools should be considered.

### FMS Levels Worldwide

FMS proficiency worldwide is low (Bardid, Huyben et al., 2016; Cliff, Okely, Smith, & McKeen, 2009; Khodaverdi, Bahram, Khalaji, & Kajemnejad, 2013; Lester et al., 2017; O'Brien et al., 2016; Spessato, Gabbard, Valentini, & Rudisill, 2013). Mastery levels (i.e. the proportion of children who demonstrate correct performance of all skill components across all test trials) of less than 65% are typically reported in the literature. Mitchell et al. (2013) who assessed the FMS levels of 5-12 year old (N=701) children from 11 primary



schools in New Zealand, reported less than 65% mastery in 10 of 12 FMS assessed using the TGMD (exceptions being the run and slide). Using the Get Skilled: Get Active (NSW Department of Education and Training, 2000), Barnett, van Beurden, Morgan, Brooks, and Beard (2010) also reported less than 65% mastery/near mastery (i.e. all components present/all but one component present) in all six skills assessed in their study (catch, kick, overhand throw, side gallop, vertical jump and hop) among 10 year old Australian children (N=276). Lower mastery levels were reported by Bryant, Duncan and Birch (2014) among 6-11 year old British children on assessment of their FMS using the Process Orient Checklist of the New South Wales 'Move It, Groove It' (NSW Department of Health, 2003). When 8 FMS (the sprint run, side gallop, hop, kick, catch, overarm throw, vertical jump and static balance) were assessed among this cohort, mastery levels didn't even exceed 35% and ranged from 3.3% (in the sprint run) to 33.5% (in balance).

Recent trends indicate lower FMS proficiency among the current generation of children when compared to their predecessors (Cliff et al., 2009; Spessato, Gabbard, Valentini, et al., 2013). The normative sample of the TGMD-2 consists of data from 1,208 USA children aged 3-10 years which was collected between 1997 and 1998. Gross Motor Quotient (GMQ) categories (N=7) have been calculated using this sample and range from very poor to very superior (very poor: <70, poor: 70-79, below average: 80-89, average: 90-110, above average: 111-120, superior: 121-130, very superior: >130). Some recent studies that have used the TGMD-2 have reported 'average' FMS levels among children (Bardid, Huyben, et al., 2016; Cliff et al., 2009). However, it should be noted that the GMQ mean scores reported in these studies fall towards the lower end of the 'average' category. Bardid, Huyben, et al. (2016) reported a GMQ score of 93.2 among 3-6 year old Belgian children, while Kordi, Nourian, Ghayour, Kordi, and Younesian (2012) reported a mean GMQ score of 93.3 among 4-6 year old children (N=147) from Iran. Numerous other studies have reported 'below average' FMS levels among children (Bardid, Huyben, et al., 2016; Burrows, Keats, & Kolen, 2014; Cliff et al., 2009). Bardid, Huyben, et al. (2016) reported GMQ mean scores ranging between 85.4 and 89.1 among 7-8 year old Belgian children while Cliff et al. (2009) reported GMQ mean scores of 88.2 among 3-5 year old Australian boys. Burrows et al. (2014) among 6-10 year old children

from Canada also reported 'below average' FMS scores (ranging from 83.2-89.2). Furthermore, 'poor' FMS levels (mean GMQ =  $76.3 \pm 9.28$ ) have been reported among Iranian girls (N=352, mean age:  $8.7 \pm 0.3$  years) (Khodaverdi et al., 2013). A study by Spessato, Gabbard, Valentini, et al. (2013) who presented FMS proficiency in terms of age equivalent values, reported that 5-10 year old Brazilian children could only demonstrate proficiency levels equal to those demonstrated by younger children from the normative sample of the TGMD-2 (Ulrich, 2000). For example, 9-10 year old Brazilian children's locomotor skill level was equal to the proficiency level demonstrated by 5-year olds in the normative sample. These findings highlight the sub-optimal FMS proficiency levels of children today.

### FMS of Irish Youth

To date, there is a limited amount of literature relating to the FMS proficiency of Irish primary school children. One of the few studies that has assessed the FMS proficiency of a cohort of Irish children was carried out by Breslin et al. (2012). This study measured the FMS proficiency of 7-8 year old children (N=177) in Northern Ireland. A total of 10 FMS were assessed using an adapted version of two existing FMS assessment tools; the Bruininks-Oseretsky Test of Motor Proficiency (Bruininks, 1978) and the Movement Assessment Battery for Children (Henderson & Sugden, 1992). Skills assessed were the standing broad jump, jump-half turn, overarm throw, kick, the trapping (of a ball), the catching (of a ball), balance on one foot and the log roll. The catching, throwing, trapping and kicking of a ball in a simple game, drill or movement sequence was also assessed. While the mean and standard deviation scores were reported, the level of proficiency of each of the skills could not be determined owing to the omission of the possible score ranges and the use of a novel assessment tool. Furthermore, no information relating to the scoring protocol used was reported. Given these limitations, the proficiency level of the cohort of Irish children relative to test norms and children from other studies cannot be determined.

The only other study to assess the FMS proficiency of an Irish primary school cohort was conducted by Farmer et al. (2017) among 160 girls (mean age:  $10.69 \pm 1.40$  years). A total of seven FMS (taken from three separate FMS assessment tools; the TGMD, TGMD-

2 and Get Skilled: Get Active) were measured. The skills tested were the run, skip, vertical jump, stationary dribble, catch, kick and balance. The study revealed that only 1.9% of girls demonstrated mastery across all seven skills tested. Furthermore, less than 40% of girls demonstrated mastery in the vertical jump and skip. The highest level of mastery was found in the kick. However, the mastery level demonstrated in this skill still failed to exceed 70% (68% mastery reported), highlighting the poor FMS proficiency of Irish girls.

A study among Irish adolescents (N=223, mean age:  $12.3 \pm 0.49$  years) assessed 9 FMS which were selected from three existing FMS assessment tools; the TGMD (Ulrich, 1985), the TGMD-2 (Ulrich, 2000) and the Victorian FMS Manual (Department of Education Victoria, 1996). The study reported very low levels of FMS proficiency with only 1 adolescent (<0.1%) able to demonstrate mastery of all 9 FMS assessed in the study and only 11% able to demonstrate mastery/near mastery in all 9 of the skills (O'Brien et al., 2016). Lester et al. (2017) among a cohort of 12-16 year old (1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> year) Irish adolescents (N=181; mean age:  $14.42 \pm 0.98$  years) also reported low proficiency levels with no adolescent able to demonstrate mastery in all 10 of the FMS assessed in the study. Furthermore, the proportion of children from each year group (i.e. 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> year) that demonstrated mastery, failed to exceed 50% for 6 of the 10 skills assessed. Given that children have the potential to master FMS by the age of 6 (Gallahue & Ozmun, 2006), these FMS levels reported among Irish adolescents indicate that Irish adolescents cannot correctly perform a range of basic movement skills and thus interventions are required prior to this age i.e. during the primary school years (and/or during the preschool years).

### Sex-Related Differences in FMS

Sex-related differences in FMS have been observed across numerous studies (Cohen, et al., 2014; Lin & Yang, 2015; O'Brien et al., 2016). Boys are commonly reported to have higher overall FMS proficiency than girls (Barnett, van Beurden, Morgan, Brooks, & Beard, 2008; Lin & Yang, 2015; O'Brien et al., 2016). Among a cohort of 6-9 year old children (N=485) from Taiwan, Lin and Yang (2015) found that boys demonstrated significantly higher overall TGMD-2 scores than their female counterparts (Boys: 56.84

$\pm 8.70$ , Girls:  $52.47 \pm 8.95$ ,  $p < 0.01$ ). In contrast, Hardy, King, Farrell, Macniven, and Howlett (2010) among a cohort of 2-6 year old Australian children ( $N=425$ ), reported no significant sex-related differences in total FMS score (summed from 4 locomotor and 4 object-control skills from the TGMD-2) ( $p > 0.05$ ). Among Irish adolescents, O'Brien et al. (2016) found that boys outperformed girls when scores from 9 FMS were summed.

In terms of object-control skills, boys have been found to demonstrate superior proficiency levels when compared to their female counterparts (Barnett, van Beurden, et al., 2008; Barnett et al., 2010, Bolger et al., 2017; Cohen et al., 2014; Goodway, Robinson, & Crowe, 2010; Hardy et al., 2010; Lin & Yang, 2015; Valentini et al., 2016). Valentini et al. (2016) who assessed the FMS proficiency of Brazilian children from 18 cities across the country ( $N=2,377$ , mean age:  $7.4 \pm 1.9$  years) using the TGMD-2, found that boys had a significantly higher object-control subset score than girls (Boys:  $31.1 \pm 8.7$ , Girls:  $24.0 \pm 7.7$ ,  $p < 0.01$ ) and also scored significantly higher in all 6 object-control skills assessed (catch, throw, roll, dribble, kick, strike) ( $p < 0.01$ ). Cohen et al. (2014) examined sex differences among children from low-income communities ( $N=460$ , mean age:  $8.5 \pm 0.6$  years) and similarly, found that boys scored significantly higher than girls in object-control subset score (assessed using the TGMD-2) (Boys:  $26.8 \pm 6.0$ , Girls:  $21.9 \pm 5.3$ ,  $p < 0.01$ ). Lin and Yang (2015) also found that boys outperformed girls in object-control subset score using the TGMD-2 and further analysis revealed that boys scored significantly higher in four (strike, dribble, throw, roll) of the six object-control skills assessed ( $p < 0.01$ ) (with no sex-related difference observed in the catch or kick). Furthermore, Barnett et al. (2010) among 10 year old Australian children ( $N=276$ ) found that a significantly larger proportion of boys achieved mastery than girls in the catch (62.1 vs. 44.8%,  $p < 0.01$ ), kick (56.8 vs. 13.3%,  $p < 0.01$ ) and throw (48.5 vs. 13.4%,  $p < 0.01$ ). Meanwhile, others have reported no sex-related differences in object-control proficiency (Bakhtiar, 2014; Kordi et al., 2012).

Sex-related analysis of locomotor skill competency has found mixed results. Some research has reported higher locomotor proficiency among girls than boys (Cohen et al., 2014; Hardy et al., 2010) while others have reported no sex-related difference (Barnett et al., 2010; Barnett, Lubans, Salmon, Timperio, & Ridgers, 2018; Goodway, Robinson, &

Crowe, 2010; Kordi et al., 2012; Lin & Yang, 2015). Lin and Yang (2015) found no sex-related difference in locomotor subset scores nor any of the 6 locomotor skills (run, leap, hop, gallop, slide and horizontal jump) assessed in their study. Barnett et al. (2010) reported higher locomotor proficiency among girls. However, similar to Lin and Yang (2015), the difference was not significant ( $p>0.05$ ). While findings by Spessato, Gabbard, Valentini, et al. (2013) among 3-4 and 5-6 year old Brazilian children also support the findings of Lin and Yang (2015) and Barnett et al. (2010) with no sex-related difference reported, results among 7-8 and 9-10 year olds in the study revealed significantly higher locomotor scores among boys than girls. Valentini et al. (2016) also reported higher locomotor subset scores among Brazilian boys than their female counterparts (Boys:  $28.8 \pm 7.0$ , Girls:  $27.8 \pm 6.7$ ,  $p<0.01$ ), and also significantly higher raw skill scores in three (run, gallop and jump) of six locomotor skills assessed ( $p<0.01$ ).

Due to the similar biological characteristics of prepubescent boys and girls (Malina, Bouchard, & Bar-Or, 2004), sex-related differences in FMS proficiency have been largely attributed to environmental factors. The nature of physical activities and games that boys and girls partake in, which are most likely influenced by family, teachers and peers (Bardid, Huyben, et al., 2016; Booth et al., 2006; Garcia, 1994; Hardy et al., 2010; Thomas & French, 1985) has been highlighted as one such factor. It has been reported that boys more commonly engage in object-control related sports and activities such as soccer, while girls are more likely to engage in dance and gymnastics (Booth et al., 2006). It has been reported that more boys participate in team sports than girls and between those who participate in team sports, boys participate more often (Field & Temple, 2017). The object-control related nature of many team sports (e.g. soccer, hockey, basketball) and this greater participation in team sports by boys may explain the commonly reported sex-related differences in object-control and overall FMS proficiency due to the greater instruction, coaching and practice engaged in as a result (Field & Temple, 2017).

#### Age-Related Differences in FMS

Few studies have investigated age-related differences in FMS proficiency across childhood using statistical tests. However, studies that have reported FMS levels of different aged children (6-9 years) within the same study show a trend of increasing FMS

proficiency (raw scores) with age (Mukherjee, Jamie, & Fong, 2017; Pang & Fong, 2009). Age-related differences in FMS proficiency levels have been reported among children (Bardid, Huyben, et al., 2016; Freitas et al., 2015; Lin & Yang, 2015; Mitchell et al., 2013; Spessato, Gabbard, Valentini, et al., 2013). Lin and Yang (2015) who investigated the age-related differences in FMS between 6-7, 7-8 and 8-9 year old children using the TGMD-2, found significant differences in locomotor, object-control and overall FMS scores between the age groups ( $p < 0.01$ ). It was reported that the 8-9 year olds performed significantly better than the 6-7 and 7-8 year olds in locomotor, object-control and overall FMS ( $p < 0.01$ ), while the 7-8 year olds scored significantly higher than the 6-7 year olds at locomotor skills ( $p < 0.01$ ). Age-related differences were also reported by Bardid, Huyben, et al. (2016) who measured FMS proficiency among a cohort of 3-8 year old Belgian children ( $N=1,614$ ) using the TGMD-2. The study revealed that the children aged 4, 5, and 6 years of age scored significantly higher in locomotor skills than children who were one year younger than them ( $p < 0.05$ ). However, there was no significant difference in locomotor skill score between children aged 7 and 8 and their counterparts who were one year younger ( $p > 0.05$ ). For object-control skill score, children of all ages scored significantly higher than those one year younger ( $p < 0.01$ ). Similarly, Valentini et al. (2016) who assessed the FMS proficiency of 3-10 year olds from 18 cities across Brazil ( $N=2,377$ , mean age:  $7.4 \pm 1.9$  years) using the TGMD-2, found that locomotor subset score increased significantly with age, specifically from 3 years to 4 years, and also 4 years to 5 years ( $p < 0.05$ ). Significant increases in object-control subset scores were found with every increase in age ( $p < 0.05$ ) (with the exception of the 4 to 5 year old period). Age-related differences in FMS have been attributed to maturation, and the greater instruction, practice and feedback afforded to older children (Charlesworth, 2016; Freitas et al., 2015). Findings by Mitchell et al. (2013) which report that younger children's FMS proficiency surpassed the older children's baseline FMS proficiency following an intervention reinforce suggestions that age-related differences in FMS are due to greater time for opportunities for learning, practice and reinforcement of the older children.

## **2.3 Markers of Health**

This section provides an overview of a number of markers of health; overweight/obesity, CRF and PA. A definition of each marker of health and the benefits associated with each, are outlined. A number of key issues regarding the measurement of each of the markers of health are presented and discussed. This section also reviews the current levels of overweight/obesity, CRF and PA among children and discusses the relationship between each marker of health and FMS among children.

### **2.3.1 Overweight and Obesity**

Overweight and obesity are defined as the accumulation of abnormal or excessive levels of body fat that is associated with a risk of adverse health (Sahoo et al., 2015; WHO, 2017d). Increases in body fat arise from a positive energy balance whereby energy intake exceeds energy expenditure (Sahoo et al., 2015) and thus is potentially influenced by diet and PA (Government Office for Science, 2007; Lobstein et al., 2004; WHO, 2002).

Overweight/obesity has been found to track from childhood to adulthood (Evensen et al., 2016; Johannsson, Arngrimsson, Thorsdottir, & Sveinsson, 2006; Serdula et al., 1993; Simmonds et al., 2016). A meta-analysis of 15 large cohort studies conducted by Simmonds et al. (2016) reported that obese children were 5.2 times more likely to be obese adults when compared to their non-obese counterparts. A systematic review by Reilly and Kelly (2011) found that childhood and adolescent overweight and obesity were significantly associated with adverse health in adulthood. The review revealed that overweight and obese youth were 1.4 to 2.9 times more likely to experience premature death than their non-overweight counterparts. With hazard ratios of 1.1 to 5.1 reported, childhood and adolescent overweight and obesity were also significantly associated with increased risk of adult cardiometabolic morbidity (i.e. diabetes, hypertension, heart disease and stroke). Significantly increased risks of disability, asthma, symptoms of polycystic ovary syndrome (Reilly & Kelly, 2011) and coronary heart disease (Baker, Olsen, & Sorensen, 2007) during adulthood have also been reported for overweight and obese youth.

Childhood overweight and obesity is among the most serious health issues worldwide (Sahoo et al., 2015) and costs the Republic of Ireland an estimated €1.7 million in direct health expenses every year (Perry et al., 2017). Childhood overweight and obesity are associated with numerous physical, psychological and social problems. Associated medical conditions include fatty liver disease, sleep apnoea, type 2 diabetes, asthma, cardiovascular disease risk factors, high cholesterol, glucose intolerance, skin conditions, impaired balance and orthopaedic issues (e.g. flat feet, sprains, increased risk of fractures) (Lobstein et al., 2004; Niehoff, 2009; Saha, Sarkar, & Chatterjee, 2011). In a study by Saha, Sarkar and Chaterjee (2011) among children aged 6-11 years (N= 94) from Kolkata, hyperinsulinemia and insulin resistance was reported among 61% and 63% of children who were overweight/obese according to the Center for Disease Control and Prevention's (CDC) criteria for age- and sex-specific BMI cut-points (Center for Disease Control and Prevention, 2016; Cole, Bellizzi, Flegal, & Dietz, 2000) while dyslipidemia was also observed in 41% of obese children in the study. A review of the psychosocial impact of overweight/obesity on children (Cornette, 2008) found that overweight/obesity was associated with issues such as low self- and body-esteem, anxiety and body dissatisfaction. Evidence has found that overweight and obese children are subject to teasing, bullying, negative stereotyping, discrimination and social marginalisation because of their adiposity level (Budd & Hayman, 2008; Schwimmer, Burwinkle, & Varni, 2003). They also tend to have fewer friends (Niehoff, 2009) and more problems at school than normal weight children (Schwimmer et al., 2003).

### Measuring Adiposity

There is no 'gold standard' for measuring body fat (D. O'Neill, 2015; Weber, Leonard, & Zemel, 2012). A number of measures (direct and indirect) are commonly used to quantify body fat. Direct measures include dual energy X-ray absorptiometry (DXA), underwater weighing, magnetic resonance imaging (MRI) and computerized axial tomography (CT), while indirect methods measure relative fatness of individuals using anthropometric measurements and include skinfold thickness, WC, hip circumference or indices derived from these measurements and height and body mass (e.g. BMI, WHtR). While numerous measures of body fat exist, it should be noted that body fat values may differ depending on what method of measurement is used (Eisenmann,



Heelan, & Welk, 2004; J. L. O'Neill et al., 2007). Eisenmann et al. (2004) who measured the body fat of USA children (N=75, mean age= 5.8 ± 1.2 years) by skinfolds (using four different equations), BIA and DXA, reported different body fat percentage scores for all measures. Body fat percentages reported using the skinfold equations ranged from 17% to 18.3%, while the body fat percentage scores using BIA and DXA were 16.8% and 19.2%, respectively. While different body fat percentage values may be obtained depending on the measure used, it should be noted that Eisenmann et al. (2004) reported a significant moderately high correlation ( $r=.75$ ,  $p<0.05$ ) between BMI and DXA. Research conducted by Brambilla et al. (2013) among 8-18 year olds (N=2339) found that WHtR was a better predictor of body fat percentage than BMI with linear regression analysis revealing that WHtR predicted 64% of the variance in body fat percentage, while BMI only predicted 32% of the variance in body fat percentage. However, a systematic review by Jensen, Camargo and Bergamaschi (2016) that compared methods used to measure body fat in 7-10 year old children, found a strong correlation between BMI and body fat but only a moderate correlation between WHtR and body fat. A systematic review and meta-analysis by Martin-Calvo, Moreno-Galarrage, and Martinez-Gonzalez (2016) reported that body fat measured by DXA was moderately-strongly correlated with body fat measured by both BMI ( $R^2$  range: 0.32-0.91) and WHtR ( $R^2$  range: 0.49-0.73) among youth, suggesting that **both** BMI and WHtR are useful proxy measures of adiposity among children.

Dual energy x-ray absorptiometry (DXA) is a non-invasive method that can be used to measure body fat in children (Helba & Binkovitz, 2009; S. Y. Lee & Gallagher, 2008) and is considered among the most accurate methods for the measurement of body fat (Helba & Binkovitz, 2009; Lifshitz et al., 2016; Shypailo, Butte, & Ellis, 2008) and is often used as a criterion measure for other methods of body composition among children (Cameron et al., 2004; Eiberg et al., 2004; Eisenmann et al., 2004; Frisard, Greenway, & Delany, 2005). DXA works by passing two low energy x-ray beams of differing energy levels through the body. The beams are subsequently attenuated differentially by the different tissues in the body (i.e. bone mineral tissue and soft tissue), with soft tissue sub-divided into lean and fat mass using calibration equations (Goran, Driscoll, Johnson, Nagy, & Hunter, 1996; Rothney, Brychta, Schaeffer, Chen, & Skarulis, 2009). It should be

noted that DXA scanning involves exposure to radiation. However, the amount of radiation is small; equivalent to 1-10% of that of a chest X-ray (S. Y. Lee & Gallagher, 2008). Furthermore, as measuring body fat by DXA requires large, expensive equipment (that are typically found in medical facilities or physiology laboratories), a skilled technician, takes approximately 20 minutes per test and requires the individual to lie stationary on the DXA machine (Figure 2.3) for the duration of the testing procedure, DXA is not a practical method for use in studies of large numbers of children.



**Figure 2.3:** A dual energy X-ray absorptiometry (DXA) scanner

BMI is a common, quick, non-invasive method used as an index of relative adiposity. It is calculated as body mass (kg)/height squared ( $m^2$ ). For adults, cut-off points of 25  $kg/m^2$  and 30  $kg/m^2$  are used respectively, for overweight and obesity thresholds. As BMI varies with age and sex (Lobstein et al., 2004), various different cut-off points (based on different reference populations) have been recommended to classify children into BMI categories (Cole et al., 2000; Cole, Freeman, & Preece, 1995; Kuczmarski, 2000; Must, Dallal, & Dietz, 1991; Rolland-Cachera et al., 1991; WHO, 1995).

It has been found that BMI is significantly correlated with DXA ( $r=.75$ ,  $p<0.05$ ) among children (Eisenmann et al., 2004). While observer and measurement error when using BMI is low (Lobstein et al., 2004), BMI is limited in that it may not be a sensitive measure of adiposity in people of extreme sizes (e.g. very short or tall individuals or those with an unusual distribution of body fat). A further limitation to BMI is that it cannot distinguish between fat and fat-free mass, and thus often incorrectly categorises individuals with large fat-free masses (McCarthy & Ashwell, 2006).

Numerous age- and sex-specific BMI cut-points have been developed for use among children (Cole et al., 1995; Cole et al., 2000; Must et al., 1991; Rolland-Cachera et al., 1991; WHO, 1995). There is no consensus on which set of cut-off points should be used to determine overweight and obesity among children (Sahoo et al., 2015), making it difficult to compare findings across research (Lobstein et al., 2004; Martin-Calvo et al., 2016). Cut-points have been developed from reference populations from the USA by Must et al. (1991) and more recently by the CDC (Kuczmarski, 2000). Other cut-points have been developed from reference populations from the UK (Cole et al., 1995) and France (Rolland-Cachera et al., 1991) while cut-points from international reference populations have been developed by the World Health Organisation (WHO) (de Onis et al., 2007) and the International Obesity Taskforce (IOTF) (Cole et al., 2000). The WHO defines overweight and obesity as BMI values greater than 1 and 2 standard deviations from the mean of the reference population, respectively. The reference population used for the WHO cut-points was drawn from a combination of (i) the 1977 National Center for Health Statistics/WHO Growth reference (1-24 years) (WHO, 1995) and (ii) data from pre-school children under the age of 5 (taken from the WHO Child Growth Standards. The reference population used for these cut-points therefore included children and adolescents from the US, Norway, Brazil, Ghana and India). The IOTF cut-points for children aged 2-18 years are based on representative data from the USA, Great Britain, Brazil, China, Holland and Singapore and are linked with the IOTF's adult BMI cut-point values for overweight (i.e. 25 kg/m<sup>2</sup>) and obesity (i.e. 30 kg/m<sup>2</sup>) (Cole et al., 2000). In addition to these BMI cut-points for overweight and obesity among children, Cole, Flegal, Nicholls, and Jackson (2007) have also developed age and sex-specific BMI cut-points to identify three grades of thinness ('thinness grade 3', 'thinness grade 2' and 'thinness grade 1') among children and adolescents. These cut-points were developed using the same data that were used to develop the IOTF cut-points for overweight and obesity (Cole et al., 2000). BMI values for 'thinness grade 3', 'thinness grade 2' and 'thinness grade 1' correspond with adult BMI values of 16, 17 and 18.5, respectively. Findings from studies that have used different cut-points cannot accurately be compared. A study conducted by J. L. O'Neill et al. (2007), which estimated the prevalence of overweight and obesity in 5-12 year old Irish children (N=596) using IOTF (Cole et al., 2000), CDC (Kuczmarski, 2000) and British 1990 (Cole et al., 1995) BMI cut-

points, found that the prevalence of overweight ranged from 10.5-15.3% among boys and 11.6-19.6% among girls, while the prevalence of obesity ranged from 4.1-9.2% among boys and 9.3-14.3% among girls, depending on what cut-points were used. Others have also reported discrepancies in results relative to the cut-points selected (Flegal, Ogden, Wei, Kuczmarski, & Johnson, 2001; Shields & Tremblay, 2010; Wang & Wang, 2002). Shields and Tremblay (2010) found that the prevalence of overweight among Canadian youth (aged 2-17 years) was higher when categorised using the WHO cut-points (35%) compared to the CDC (28%) and IOTF (26%) cut-points. The prevalence of obesity was similar using the WHO and CDC cut-points (13%) but lower using the IOTF cut-points (8%). It should be noted that the IOTF cut-points appear to be conservative in the estimation of overweight/obesity prevalence when compared to others (Lobstein et al., 2004; Shields & Tremblay, 2010; Wijnhoven et al., 2014).

Presenting BMI z-scores is another method that has been extensively used in childhood overweight/obesity research to report childhood adiposity levels. BMI z-scores are calculated as  $[(\text{observed value}) - (\text{median reference value of a population}) / \text{SD of reference population}]$ . A z-score of 0 is equal to the median (50<sup>th</sup> centile value), a z-score of 1 is equal to the 84<sup>th</sup> centile, a z-score of 2 is approx. equal to the 98<sup>th</sup> centile and a z-score of 2.85 is >99<sup>th</sup> centile. While BMI z-scores are used to compare against a reference population, choosing an appropriate reference population is often difficult.

While the use of different cut-points (based on different reference populations) makes it difficult to compare findings in published literature (Wang & Wang, 2002), some researchers suggest that using the same reference for all children may not be appropriate as biological differences in body composition, build, maturation status and the relationships between BMI and markers of health vary between populations (Deurenberg, Yap, & Van-Staveren, 1998; Deurenberg, 2001; Ellis, 1997; Reilly, 2002). As no age- and sex-specific BMI cut-points have been developed from an Irish reference population, J. L. O'Neill et al. (2007) suggest that the British 1990 cut-points of Cole et al. (1995) may be the most appropriate for use among Irish children. However, despite these suggestions, the IOTF cut-points have been widely used in previous studies to determine the adiposity level (as measured via BMI-based categories) of Irish youth (Bel-

Serrat et al., 2017; Layte & McCrory, 2011; J. L. O'Neill et al., 2007; Whelton et al., 2007; Woods et al., 2010) and so perhaps it may be more appropriate to use the IOTF cut-points to allow comparisons to be made between these studies and also to identify trends in the data.

WHtR is a proxy measure of central (abdominal) adiposity (Ashwell, Cole, & Dixon, 1996; Roriz et al., 2014) and has been found to be a better predictor of cardiovascular disease (CVD) risk factors than BMI in children (Savva et al., 2000). WHtR is calculated using the following formula: waist circumference (cm)/height (cm). It should be noted that a number of different protocols have been used to measure WC (Mason & Katzmarzyk, 2009; Sant'Anna et al., 2009). In a study by Coppinger et al. (2016), WC was measured as the smallest circumference around the abdominal region between the lower costal (10<sup>th</sup> rib) border and the top of the iliac crest. In contrast, Brambilla, Bedogni, Heo, and Pietrobelli (2013) measured WC at the highest point of the iliac crest while Swainson, Batterham, Tsakirides, Rutherford, and Hind (2017) measured WC at the mid-point between the lowest rib and the iliac crest. The circumference of the abdominal region at the umbilicus has also been used as a measurement site for WC (Mason & Katzmarzyk, 2009). A study by Swainson et al. (2017) reported that WHtR (with WC measured at the midpoint of the abdominal region between the lowest rib and the iliac crest) was the best predictor of five anthropometric measurements (BMI, WC, hip to height ratio, WHtR and weight/height) for measuring total body fat percentage and visceral adipose tissue among adults (N=81, mean age: 38.4 ± 17.5 years). Further to this, Brambilla et al. (2013) found that WHtR (with WC at the highest point of the iliac crest) is a better predictor of body fat percentage, trunk fat percentage and fat mass index (measured using DXA) than both WC and BMI among children. In fact, WHtR explained 64% of the variance in body fat percentage, while WC and BMI explained only 31% and 32% of the variance, respectively (Brambilla et al., 2013).

The use of WHtR as measure of adiposity has been encouraged for children as WC and height are simple and cheap to measure, with results highly reproducible given the ease at which the bony landmarks required for measurement can be located (McCarthy & Ashwell, 2006; Ross et al., 2008).

### Prevalence of Overweight/Obesity

In 2015, 107.7 million children worldwide were predicted to be classified as obese (GBD 2015 Obesity Collaborators, 2017). A systematic analysis of global, regional and national rates of overweight and obesity conducted for the Global Burden of Disease Study 2013, reported that 23.5% of boys (<18 years of age) and 22.6% of girls (<18 years of age) from developed countries were either overweight or obese in 2013 (Ng et al., 2014). The prevalence overweight and obesity among children and adolescents varies across nations worldwide (Ahrens et al., 2014; Lobstein et al., 2004; Ng et al., 2014; Wang & Lim, 2012), with rates of 30-40% found in the Americas and the eastern Mediterranean, 20-30% in Europe and 10-20% in south-eastern Asian, western Pacific and African regions (Wang & Lim, 2012).

The highest prevalence of childhood overweight/obesity in Europe is reported among countries located in the south (Ahrens et al., 2014; Lobstein et al., 2004; Wijnhoven et al., 2014). The WHO European Childhood Obesity Surveillance found that based on the WHO cut-points (de Onis et al., 2007), over 40% (over 30% using IOTF cut-points), of 7-, 8- and 9-year old boys and girls from Spain were overweight/obese while an even greater proportion of 7- and 9-year old children from Greece were overweight/obese (57.2% of boys and 50.0% of girls using WHO cut-points, and 45.1% and 42.3% using IOTF cut-points) (Wijnhoven et al., 2014). Lower overweight/obesity rates were reported among children from countries in the north of Europe. Data from Belgium found that overweight/obesity rates among 7-9 year old children ranged from 18%-27.3% using the WHO criteria (10.8-21.8% based on IOTF cut-points) (Wijnhoven et al., 2014) while 15.9% and 21.7% of 4-14 year old Danish girls and boys, respectively, were overweight/obese using the IOTF cut-points (Matthiessen et al., 2014). Furthermore, it was found that only 13.3% of native Dutch children (N = 1,546; mean age: 8.2 ± 0.45 years) were overweight/obese using IOTF cut-points (Matthiessen et al., 2014). Recent data has found that in England, 22% of 4-5 year olds and 33% of 10-11 year olds were overweight and obese (NHS Digital, 2016), while in Scotland 28.8% of 2-15 year olds were overweight/obese (SPICe The Information Centre, 2015).

In Ireland, overweight and obesity are major health concerns with recent reports predicting Ireland’s projected rise to become the fattest of 53 EU countries (Webber et al., 2014). The most recent data collected as part of the Childhood Obesity Surveillance Initiative in the Republic of Ireland found that in 2015, 16.9% of first class children (6-7 years), 20.2% of 4<sup>th</sup> class children (9-10 years) and 20.6% of 6<sup>th</sup> class children (11-12 years) were overweight/obese (Table 2.2). It should be noted that higher overweight/obesity rates have been reported among girls than boys (Bel-Serrat et al., 2017; Keane, Kearney, Perry, Kelleher, & Harrington, 2014; Whelton et al., 2007). Additional findings relating to the overweight/obesity rates of Irish youth that have been reported since 2010 are presented in Table 2.2.

**Table 2.2:** Prevalence of overweight/obesity reported from national samples of Irish children (all derived from objectively measured height and mass measurements and using IOTF BMI cut-points)

Class Group	Age Range	N	Prevalence of Overweight/Obesity (%)			Study
			Girls	Boys	Girls and Boys (combined)	
1 <sup>st</sup> Class	6-7	1531	20.4	13.2	16.9	(Bel-Serrat et al., 2017)
4 <sup>th</sup> Class	9-10	1647	24.8	14.5	20.2	
6 <sup>th</sup> Class	11-12	1731	22.9	18	20.6	
Primary (5 <sup>th</sup> /6 <sup>th</sup> ) and secondary school	10-18	1215	-	-	22	(Woods et al., 2010)
Primary (Junior infants, 2 <sup>nd</sup> , 4 <sup>th</sup> , 6 <sup>th</sup> ) and secondary school (3 <sup>rd</sup> year)	4-16	17,508	23	28	-	(Whelton et al., 2007)
6 year olds	6	376	29	18	-	
9 year olds	9	237	31	22	-	
11 year olds	11	765	29	27	-	
5-8 year olds	5-8	297	30.5	19.2	-	(J. L. O’Neill et al., 2007)
5-12 year olds	5-12	596	28.9	19.4	-	
9-12 year olds	9-12	299	27.3	19.5	-	
9 year olds	9	8568	30	22	26	(Layte & McCrory, 2011)

Research examining trends in overweight/obesity has reported increases in its prevalence among children (GBD 2015 Obesity Collaborators, 2017; Lobstein et al., 2004; J. L. O’Neill et al., 2007; Wang & Lobstein, 2006). Such increases have been attributed to increases in caloric intake often from energy-dense foods and sugary drinks, as well as increases in portion sizes (Anderse & Butcher, 2006; Lobstein et al., 2004) and reductions in PA levels (GBD 2015 Obesity Collaborators, 2017; Gungor,

2014). These altered lifestyle habits are believed to be due to the development and availability of sedentary technologies, less opportunities to be physically active and less safe environments to be active in (Andersen & Butcher, 2006; Lobstein et al., 2004).

It has been reported that the prevalence of childhood overweight/obesity was increasing at approximately 0.5% per year in countries such as Brazil and the USA and at a higher rate of 1% per year in countries such as the UK, Canada and Australia in the latter part of the last century (Lobstein et al., 2004). Similarly in Ireland, increases in the overweight/obesity rates have been reported among children (J. L. O'Neill et al., 2007). A study by J. L. O'Neill et al. (2007) compared the prevalence of overweight/obesity among 5-12 year old Irish children collected in 2005 (N=596) to that of 8-12 year old children in 1990 (P. Lee & Cunningham, 1990) and found a significant increase in the rates of overweight and obesity observed (regardless of whether overweight and obesity were defined using CDC, IOTF or British 1990 cut-points) ( $p < 0.01$ ). In contrast to these findings, recent reports by Keane, Kearney, Perry, Kelleher, et al. (2014) and Bel-Serrat et al. (2017) suggest that overweight/obesity rates are stabilising/declining. It must be noted however, that these trends were found across a relatively short period of time ( $\leq 10$  years). Bel-Serrat et al. (2017) reported that the prevalence of overweight and obesity (using IOTF cut-points) among first class children (approx. 6-7 years) decreased significantly between 2008 and 2015 with rates of 21.6%, 20.8%, 16.8% and 16.9% reported for 2008, 2010, 2012 and 2015, respectively ( $p < 0.05$ ). A decreasing trend was also observed among 3<sup>rd</sup> class children (approx. 9-10 years old) with prevalence of overweight/obesity of 23.5% and 22.4% reported among boys in 2010 and 2012 respectively, and rates of 30% to 26.5% reported among girls in 2010 and 2012 (Bel-Serrat et al., 2017). In contrast, a systematic review of the trends and prevalence of overweight and obesity (IOTF cut-points) among school children (approx. 4-12 years) from the Republic of Ireland (which included 4 national and 10 regional based studies), reported similar rates of overweight/obesity across the 10 year period between 2002 and 2012 (Keane, Kearney, Perry, Kelleher, et al., 2014). Despite these findings that suggest that Ireland's childhood overweight/obesity rates are stabilising/declining, it has been reported that Ireland are ranked in the top 30% (of 200 countries) on the overweight/obesity level chart (NCD Risk Factor Collaboration, 2017). Furthermore, in a



study of 30 developed countries, Irish boys were ranked 9<sup>th</sup> highest and Irish girls were ranked 5<sup>th</sup> highest on the overfat chart ('overfat' was defined as carrying excess body fat that can impair health) (Maffetone, Rivera-Dominguez & Laursen, 2017). Given the adverse health conditions associated with overweight/obesity and being overfat, the prevention of and reduction in both are of high priority in Ireland.

### FMS and Adiposity

A considerable volume of research has investigated the relationship between FMS and body composition (Franjko, Zuvella, Kuna, & Kezic, 2013; Hume et al., 2008; Lubans et al., 2010; O'Brien et al., 2016b; Siahkouhian, Mahmoodi, & Salehi, 2011; Slotte, Saakslanti, Metzsamuuronen, & Rintala, 2015; Spessato, Gabbard, Robinson, & Valentini, 2013). Such examinations of the relationship between FMS and adiposity level among youth have produced mixed findings. A review by Lubans et al. (2010), which included a total of 9 studies that examined the relationship between FMS and adiposity level (the majority using BMI z-score), found that 6 of the 9 studies reported a negative relationship (i.e. lower FMS scores were associated with higher adiposity levels) while three reported no relationship. However, it should be noted that three of the 6 studies that reported a negative relationship assessed FMS using product-oriented tools (D'Hondt, Deforche, De Bourdeaudhuij, & Lenoir, 2009; Graf et al., 2004; McKenzie et al., 2002). It is difficult to compare research that has examined the relationship between FMS and adiposity level as FMS assessment tools, skills, number of skills and measures of adiposity vary across the studies.

Slotte et al. (2015) found among 8 year old Finnish children (N=304) that FMS (TOTAL FMS) proficiency (measured using the TGMD-2) was negatively correlated with four different measures of adiposity (BMI, WC, body fat percentage and abdominal fat percentage (both measured via DXA). Weak ( $r$  range: -0.259 to -0.276,  $p < 0.01$ ) and weak/moderate correlations ( $r$  range: -0.287 to -0.408,  $p < 0.01$ ) were observed between TOTAL FMS among girls and boys respectively. While small correlations were reported between OC and three measures of adiposity among boys (WC:  $r = -.200$ , body fat percentage:  $r = -.304$ , abdominal fat percentage:  $r = -.262$ ,  $p < 0.05$ ), there were no significant correlations found between OC and adiposity among girls ( $r$  range = -.157 to -

.176,  $p < 0.05$ ) (Slotte et al., 2015). Small negative correlations were reported between locomotor skill score and adiposity among boys ( $r$  range:  $-.316$  to  $-.383$ ,  $p < 0.01$ ), and girls ( $r$  range:  $-.292$  to  $-.332$ ,  $p < 0.01$ ), respectively in this study. When children were categorised as 'healthy weight' or 'overweight/obese' based on IOTF cut-points, it was found that children of a 'healthy weight' displayed significantly greater FMS proficiency than their overweight/obese counterparts in locomotor skills (LOCO;  $p < 0.01$ , large effect size), object-control skills (OC;  $p < 0.01$ , small effect size) and overall FMS (TOTAL FMS;  $p < 0.01$ , large effect size) (Slotte et al., 2015). However, it must be noted that only 5 (gallop, leap, jump, dribble, throw) of the 12 skills of the TGMD-2 were assessed and so comparability of the results is limited with other studies.

Other studies have reported mixed findings with differences between normal weight and overweight/obese children in some of the FMS (Bryant et al., 2014; Hume et al., 2008). Hume et al. (2008) reported that although normal weight children were significantly better at performing the sprint run than their overweight peers ( $p < 0.01$ ), there was no significant difference between normal weight and overweight/obese Australian children in the kick, throw, strike or vertical jump (assessed using the Department of Education Victoria, 1996 scoring protocol;  $p > 0.05$ ). Similarly, Bryant et al. (2014) found that among 241 British children aged 6-11 years, the sprint run was the only skill from 8 assessed (using the Process Oriented Checklist of the Move It: Groove It manual), in which normal weight children demonstrated superiority ( $p < 0.05$ ) compared to their overweight peers. Siahkoughian et al. (2011), among 7-8 year old children ( $N=200$ ) found that three (horizontal jump, hop and run) of eight FMS were significantly negatively correlated with BMI ( $r$  range:  $-.28$  to  $-.46$ ,  $p < 0.01$ ). It should be noted that all three of these skills are locomotor skills. In contrast to these findings, Franjko et al. (2013) who assessed all 12 FMS of the TGMD-2 among 8 year old Croatian children ( $N=73$ ), found no significant correlation between LOCO and BMI among either boys or girls ( $p > 0.05$ ). Additionally, no significant correlations were found between OC and BMI or TOTAL FMS and BMI ( $p > 0.05$ ). Despite the lack of significance between FMS and BMI in this study, a significant, moderate, negative correlation ( $r = -.42$ ,  $p < 0.01$ ) was found between FMS and body fat percentage (measured using skinfolds) among girls. No significant relationship was found among boys ( $p > 0.05$ ). While Spessato, Gabbard,

Robinson, et al. (2013) reported no significant difference in FMS proficiency between underweight, normal weight, overweight and obese children ( $p>0.05$ ); significant small and moderate, negative correlations were reported between FMS and BMI among 6 and 7 year old Brazilian children ( $r=-.30$  and  $-.40$  respectively,  $p<0.05$ ), but not 4 and 5 year olds ( $p>0.05$ ). Aalizadeh, Mohamadzadeh, and Hosseini (2014) among Iranian children ( $N=241$ , mean age:  $8.53 \pm 1.11$  years), also reported no significant correlation between OC skills (TGMD-2) and BMI ( $p>0.05$ ).

When research reports a significant relationship between FMS and BMI, it appears to be largely due to the negative relationship between locomotor skills and BMI, rather than the relationship between object-control skills and BMI. For instance, Southall, Okely, and Steele (2004) among a cohort of 131 children (mean age:  $10.8 \pm 0.7$  years) found that normal weight children had significantly higher locomotor and overall FMS scores compared to their overweight counterparts ( $p<0.05$ ), while no difference was observed in object-control skill score ( $p>0.05$ ). Similarly, O'Brien et al. (2016b) reported a significant, small negative relationship between locomotor skill score and BMI among Irish adolescent boys ( $r=-.367$ ,  $p<0.01$ ) and girls ( $r=-.341$ ,  $p<0.01$ ), but no significant relationship between object-control score and BMI among either sex ( $p>0.05$ ). Some researchers suggest that the negative relationship between locomotor skill score and BMI is due to the excessive body fat of overweight/obese youth that makes it more difficult for these individuals to move their body in various movement patterns from one location to another than their leaner counterparts (O'Brien et al., 2016b; Southall et al., 2004). Other researchers, however, argue that FMS proficiency levels when assessed using process oriented tools are independent of fitness (cardiorespiratory and muscular endurance) and physical attributes (height and mass) as the skills are performed over such a short time frame (Kim & Lee, 2017). The difference in participation levels between non-overweight and overweight/obese children in organised and non-organised sport and PA may explain the proficiency difference between children of various adiposity levels. Overweight/obese children are less likely than their leaner peers to participate in organised sport (Kobel et al., 2014) where they can receive quality FMS instruction, correction and feedback from coaches and also spend time practicing basic movement skills. Overweight/obese children are also less likely to participate in non-organised

sport and PA (Kobel et al., 2014) and thus are less likely to (i) engage in the practice of FMS and (ii) receive instruction and feedback from parents or significant others that may be present during this time.

As noted previously, numerous different measures may be used to quantify body fat among children. These include DXA, BIA, BMI, WC, WHtR and skinfold measurements. A considerable amount of research that has examined the relationship between FMS proficiency and adiposity level has done so using a BMI-based measure (e.g. BMI, BMI z-score) while no research to date has examined the relationship between FMS and WHtR. Support for the use of BMI-based measures to quantify the adiposity level of children comes from a systematic review by Jensen et al. (2015) who found a stronger correlation between BMI and body fat than between WHtR and body fat among 7-10 year olds. However, in contrast, Brambilla et al. (2013) found that WHtR was a better predictor of adiposity among children and adolescents than BMI. A meta-analysis conducted by Martin-Calvo et al. (2016) reported that neither BMI nor WHtR demonstrated superiority over the other in determining obesity and so both appear to be valuable measures of adiposity.

### **2.3.2 Blood Pressure (BP)**

BP is the force of the blood pushing against the artery walls beats (Irish Heart Foundation, 2018). Each beat of the heart pumps blood to the arteries. Systolic BP is the force of the blood in the arteries when the heart beats while diastolic BP is the force of the blood in the arteries when the heart is at rest i.e. in between the beats (Irish Heart Foundation, 2018).

High BP (hypertension) during childhood can cause heart disease, kidney disease and stroke and is now considered a significant risk factor for cardiovascular disease in later life (Chen & Wang, 2008; Malatesta-Muncher & Mitsnefes, 2012). Children with high BP (hypertension) are more likely to have hypertension in adulthood (Bao, Threefoot, Srinivasan & Berenson, 1995; Sun et al., 2007). Furthermore, normal BP during childhood is associated with a lack of hypertension in later years (Theodore et al., 2015).

Obesity, physical inactivity, high calorie intake, high salt intake and fast food intake have been identified as risk factors for high BP (Malatesta-Muncher & Mitsnefes, 2012; Tanrikulu, Agirbaslu & Berenson, 2016). Research also suggests that secondary smoking (Simmoneti et al. 2011) premature birth (Bayrakci, Schaefer, Duzova, Yigit & Bakkaloglu, 2007; Simmoneti et al., 2011) and low birth rate are risk factors for elevated BP during childhood (Edvardsson, Steinhorsdottir, Eliasdottir, Indridason & Palsson, 2012; Simmoneti et al. 2011).

### Measuring Childhood BP

Measuring BP during childhood is very important as it allows for the early detection of primary hypertension and asymptomatic hypertension which may be secondary to another disorder (Flynn et al., 2017). It has been recommended that children over 3 years of age should have their BP checked every year (Flynn et al., 2017). While the standard site at which BP is measured is the brachial artery in the upper arm, the forearm, wrist and fingers have also emerged as a measurement sites. While monitors that measure BP at the forearm, wrist and fingers have many advantages over arm monitors as they are smaller, easier to place in position and do not need to be adapted or modified for overweight or obese subjects (Leblanc et al., 2013; Pickering et al., 2005), it is important to note that SBP and DBP vary at different location sites (SBP increases and DBP decreases in more distal parts of the arterial tree) (Ogedegbe & Pickering, 2010). To date, few validation studies have been conducted using such monitors and so they are not recommended at this time (Flynn et al., 2017).

A number of BP measurement techniques have emerged including the 'auscultatory method' and the oscillometric techniques. The auscultatory method involves a cuff, a pressure display and a stethoscope (O'Brien et al., 2003). The cuff is placed on the upper arm to occlude the brachial artery. The cuff is inflated with air and then deflated with a control to allow the blood to flow again. The stethoscope is used to detect the appearance and disappearance of the audible sounds (Korotkoff sounds) that occur during constricted blood flow. The SBP is read from the pressure gauge when the Korotkoff sound appears for the first time during cuff deflation and DBP is read from the pressure gauge at the moment the Korotkoff sound disappears (Chen, Chen, Feng, Chen,

Chen, Feng, Chen & Zheng, 2017). It is often difficult to identify the appearance and disappearance of the Korotkoff sounds and thus medical training and experience is required for accurate measurement (Armstrong, 2002; Zhang et al., 2017). The pressure display was traditionally a column of mercury. However, the use of mercury in healthcare settings is now prohibited in many countries meaning that the use of mercury sphygmomanometers is no longer permitted (Ogedegbe & Pickering, 2010). The mercury sphygmomanometer has since been replaced by aneroid manometers and hybrid sphygmomanometers (which have an electronic pressure gauge instead of a column of the mercury in its structure). It should be noted that although the “gold standard” method to measure BP in children is the auscultatory method, using an aneroid manometer (Corrado, 2015), aneroid manometers are less accurate than the mercury sphygmomanometers and require calibration on a regular basis (Pickering et al., 2005). Furthermore, as previously outlined, medical training and experience is required for accurate measurement (Armstrong, 2002; Zhang et al., 2017).

Another method used to measure BP is the ‘oscillometric technique’. This technique is used by most clinical-grade automatic BP devices and analyses the pulse waves collected from the cuff during constricted blood flow. This method which is based on the fact that when the oscillations of pressure in a sphygmomanometer cuff are recorded during the gradual deflation of the cuff, the point of maximal oscillation corresponds to the mean intra-arterial pressure (King, 1967; Mauck, Smith, Geddes, Bourland, 1980; Yelderian & Ream, 1979) The oscillations commence at approximately SBP, and DBP can be estimated using algorithms. Advantages of this method are that it is less susceptible to external noise and no transducer needs to be placed over the brachial artery (Ogedegbe & Pickering, 2010). However, different brands use different algorithms, and there is no generic oscillometric technique.

Measuring children’s BP is difficult for a number of reasons including small arm dimensions, small and elastic arteries, small waveforms, large differences between brachial and aortic BP values and low amplitudes (Stergiou et al., 2018). Despite the fact that support for the measurement of childhood BP in the school setting is limited (McNiece et al., 2007; Sorof, Turner, Franco & Portman, 2004), some research suggests

that school based childhood BP measurements can be reliable (King, Meadows, Engelke & Swanson, 2006). It is currently recommended that while school-based BP measurements should not be used to diagnose hypertension, it is a useful tool to identify children who may need a formal evaluation of their BP (Flynn et al., 2017).

#### Prevalence of Hypertension among Children

The increase in childhood and adolescent hypertension rates has become a major public health issue (Lurbe et al., 2016). The prevalence of hypertension among children and adolescents varies across European countries. Mladenova & Andreenko (2015) reported that the prevalence of hypertension among 8-15 year old Bulgarian children (N=873) was 3.4%, Wysznska, Podgorska-Bednarz, Leszczak and Mazur (2017) reported that the prevalence of hypertension among Polish children and adolescents (age range: 7-18 years, N=568) was 5.8% (measured from 568 Polish 7-18 year olds) while Martin-Espinosa et al. (2017) reported that the prevalence of hypertension of 1,604 Spanish 4-6 year olds was 18.2%. Other researchers have also reported hypertension rates that range within these values (Maldonado, Pereira, Fernandes, Santos, & Carvalho, 2011; Ostrowska-Nawarycz & Nawarkyz 2007; Papandreou, Stamou, Malindretos, Rousso & Mavromichalis, 2007). To date, only one study has investigated the BP levels of Irish youth (Woods et al., 2010). The study which included both primary school (33%) and secondary school (67%) children reported that the SBP and DBP of 25% of 10-18 year olds (N=1215; mean age:  $13.4 \pm 2.1$  years) were greater than the 90<sup>th</sup> percentile for age, gender and percentile of height (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004) and thus were deemed to have an 'unhealthy BP'.

There are often inconsistencies between measurement protocols and hypertension definitions used across studies that have measured BP in children and adolescents. For instance, some studies have used the auscultatory method (Mladenova & Andreenko, 2015; Ostrowska-Nawarycz & Nawarkyz 2007; Papandreou, Stamou, Malindretos, Rousso & Mavromichalis, 2007) while others have used automatic BP monitors (Chiolero, 2008; Jackson et al., 2007; Maldonado et al., 2011; Martin-Espionosa et al., 2017). In relation to the definition of hypertension, the European Society of

Hypertension define hypertension as SBP and/or DBP greater than or equal to the 95<sup>th</sup> percentile for individuals aged up to 15 years of age (Lurbe et al., 2016) while Jackson et al. (2007) define hypertension as SBP and/or DBP greater than the 98<sup>th</sup> percentile of their sample (which was representative of children and adolescents from Great Britain). Furthermore, while hypertension rates from a single visit assessment of BP have been reported (Maldonado et al., 2011), there is a high rate of false-positive high BP readings at a single visit and multiple visits are required to confirm hypertension (Lalji & Tullus, 2018). Studies by Sorof (2004) and Chiolero, Paccaud, Burnier & Bovet (2008) support this belief that multiple visits may be necessary to identify hypertension. The study by Sorof (2004) which was carried out among 5,102 children and adolescents (10-19 years of age), found that 19% of the sample were identified as having hypertension on the first visit. Of those identified with hypertension on the first visit, 56% were identified as having hypertension on their second visit (i.e. 9.5% of the original sample had hypertension on the first two visits). Of those identified with hypertension on their first and second visit, 54% were also identified with hypertension on their third visit (i.e. 4.5% of the original sample had hypertension on all three visits). Similarly, Chiolero et al. (2008) measured BP across three visits with those with hypertension (defined as SBP and/or DBP greater than the 95<sup>th</sup> percentile) at the first visit required to attend a second time and those with hypertension on the first two visits required to attend a third time. The study which measured the BP of 5,207 children from Vaud Canton (a region in Switzerland), found that the prevalence of hypertension was 11.8%, 3.8% and 2.2% at the first, second and third visits, respectively and thus concluded that 2.2% of children had hypertension i.e. hypertension was defined as having SBP and/or DBP greater than the 95<sup>th</sup> percentile on all three occasions.

Hypertension rates increase and the severity of hypertension increases with increased adiposity (Parker et al., 2016). A study by Genovesi et al. (2008) which was carried out among 4,177 5-11 year old Italian children found that the prevalence of hypertension among those classified as normal weight, overweight and obese according to the IOTF BMI cut-points was 1.4%, 7.1% and 25%, respectively. Hypertension rates are also higher among children who have sleep-disordered breathing and chronic kidney diseases.



Research suggests that increasing PA leads to lower BP (Chen et al., 2010; Farpour-Lambert et al., 2009; Kelley, Kelley & Tran, 2003; Torrance, McGuire, Lewanczuk, McGovock, 2007). A meta-analysis of 9 randomized controlled trials found that exercise programmes with obese children with a frequency of 3 sessions per week (60+ minutes in duration) had a moderate effect on SBP while programmes of under 12 weeks with more than 3 sessions per week resulted in reductions in DBP (Garcia-Hermoso, Saavadro & Escalante, 2013). However, in contrast, a meta-analysis of 12 randomised controlled trials (representing 16 outcomes) among children and adolescents by Kelley, Kelley & Tran (2003) found declines of approximately 1% and 3% in SBP and DBP, respectively and concluded that exercise has little effect on the resting SBP and DBP of children and adolescents.

While researchers have investigated the relationship between FMS and various markers of health such as adiposity level, CRF, PA, flexibility, muscular fitness, flexibility (Lubans et al., 2010), none have examined the relationship between FMS and BP to date. Given that childhood hypertension is a significant risk factor for cardiovascular disease in later life (Malatesta-Muncher & Mitsnefes, 2012; Chen & Wang, 2008), the relationship between FMS and BP warrants attention.

### **2.3.3 Cardiorespiratory Fitness (CRF)**

CRF is the ability to transport oxygen to muscles and use this oxygen to generate energy during exercise (Armstrong & Welsman, 2007). Maximal oxygen consumption ( $VO_2\text{max}/VO_2\text{peak}$ ), the highest rate at which one can consume oxygen, is the single best indicator of CRF (American College of Sports Medicine, 1995; Shephard et al., 1968). CRF is an important marker of health among children (Mesa et al., 2006; Ruiz, Ortega, et al., 2006), so much so that it has been suggested that CRF testing should be included in health monitoring systems at a very early age (Mesa et al., 2006; Ruiz, Ortega, et al., 2006; Sandercock, Voss, McConnell, & Rayner, 2010).

A meta-analysis of 33 studies by Kodama et al. (2009) found that higher levels of CRF was associated with lower risk of all-cause mortality and coronary heart disease

(CHD)/CVD among healthy men and women. Research has also found that high CRF has a protective effect on CVD risk factors among children (S. A. Anderssen et al., 2007; Eiberg et al., 2005; Eisenmann et al., 2005; Hurtig-Wennlöf et al., 2007; Twisk, Kemper, & van Mechelen, 2000). Andersen et al. (2007) found that independent of country, age and sex, CRF was strongly negatively associated with clustered CVD risk (i.e. the presence of more than one CVD risk factor) among children. Among 9 year olds from Portugal, Denmark and Estonia, it was found that those with low CRF (in the lowest quartile) were 13.2 times more likely to have clustered risk of CVD than those with high CRF (in the highest quartile) (S. A. Anderssen et al., 2007). Eisenmann, Welk, Ihmels, and Dollman (2007) found that high levels of CRF attenuate the CVD risk among overweight children (Eisenmann et al., 2007), which provides support for suggestions that CRF may be a more important marker of health among children than BMI (Sandercock et al., 2010).

A small, negative relationship ( $r=-0.35$ ,  $p<0.01$ ) between CRF and age- and sex-adjusted metabolic syndrome score (MetS) (calculated using fasting triglyceride, blood glucose, HDL cholesterol, WC and SBP and DBP scores) has been reported among USA elementary school children (mean age:  $9.1 \pm 1.1$  years) (Burns et al., 2017). Findings from the European Youth Heart Study also reported negative associations between CRF and features of the metabolic syndrome among children 9-10 years (Ruiz, Ortega, et al., 2006).

CRF has been found to be inversely associated with total adiposity using numerous different adiposity measurement methods including skinfold thickness (Ruiz, Rizzo, et al., 2006) and DXA (Ara et al., 2004; S. J. Lee & Arslanian, 2007). An inverse relationship was also reported between CRF and abdominal adiposity (Hussey, Bell, Bennett, O'Dwyer, & Gormley, 2007; Ortega, Ruiz, Mesa, Gutiérrez, & Sjostrom, 2007). Among a cohort of 7-10 year old Irish primary school children (N=224) from Dublin, a significant inverse relationship between  $VO_2$ max and BMI z-score was found among boys ( $r=-0.43$ ,  $p<0.01$ ) and girls ( $r=-0.22$ ,  $p<0.01$ ) as well as a negative correlation between WC and  $VO_2$ max for both boys ( $r=-0.50$ ,  $p<0.01$ ) and girls ( $r=-0.33$ ,  $p<0.01$ ) (Hussey et al., 2007), suggesting that those with higher CRF levels have lower levels of adiposity.

CRF levels have also been associated academic performance (Castelli, Hillman, Buck, & Erwin, 2007; de Greeff et al., 2014). Castelli et al. (2007) reported a moderate positive relationship between CRF and maths ( $r=.49, p<0.01$ ) and also between CRF and reading ( $r=.45, p<0.01$ ) among a cohort of third and fifth grade (N=259, mean age:  $9.5 \pm 7.4$  years) USA children. Similarly, de Greeff et al. (2014) found that CRF was positively associated with maths ( $\beta=0.23, p<0.01, R^2=0.06$ ) and spelling ( $\beta=0.16, p<0.05, R^2=0.01$ ) among Dutch children (N=544, mean age:  $8.0 \pm 0.7$  years).

Low to moderate tracking of CRF from childhood to adulthood has been reported (Twisk et al., 2000; Twisk, Kemper, & van Mechelen, 2002) which highlights the importance of establishing high levels of CRF at an early age. To ensure health-promoting CRF levels (i.e. CRF levels associated with lower risk of CVD) are established in youth, CRF cut-off points have been developed for children and adolescents (Ruiz et al., 2016). A systematic review and meta-analysis of the relationship between poor CRF and CVD risk in youth found that boys with a CRF level less than 41.8 ml/kg/min were almost 6 times more likely to be at risk of CVD and girls with a CRF level less than 34.6 ml/kg/min were over 3.5 times more likely to be at risk. As a result of these findings, CRF levels of 42 and 35 ml/kg/min were identified as cut-points for CVD risk among 8-18 year old boys and girls, respectively (Ruiz et al., 2016). Cut-points for children younger than 8 have not yet been developed.

### Measuring CRF

As the rate of oxygen uptake limits the generation of energy during exercise, maximal oxygen uptake,  $VO_{2max}/VO_{2peak}$  (the highest rate at which one can consume oxygen during exercise) is the gold standard measurement of CRF (American College of Sports Medicine, 1995). An individual's  $VO_{2max}$  can be estimated directly or indirectly using maximal or submaximal tests. The gold standard for measuring CRF is graded exercise testing with indirect calorimetry. However, this laboratory based method requires sophisticated and expensive equipment, technical expertise and allows only one individual to be tested at a time. To overcome these limitations, a number of field tests have been designed and developed to estimate CRF. Field tests that are commonly used

in this regard include the 20-metre shuttle run test, the Progressive Aerobic Cardiovascular Endurance Run (PACER) and the 550m walk/run test. It should be noted however, that although the results of field tests are largely determined by the variability in children's  $VO_2\text{max}$ / $VO_2\text{peak}$ , factors such as anaerobic fitness, body composition and mass, running efficiency, motor skills, environmental factors and motivation also contribute (Armstrong & Welsman, 1994; 2007).

The 20-metre shuttle run test (20m SRT) is one of the most common field tests of CRF (Armstrong & Welsman, 2007; Batista, Romanzini, Castro-Pinero, & Vazronque, 2017). It involves participants running back and forth between two lines/markers 20m apart. The test consists of a number of stages/levels. Each stage lasts approximately 1 minute and involves a number of 20m laps/shuttles paced by an audio signal on a CD or alternative media device. The running speed required increases with each stage. Each stage (depending on the speed) consists of 7 or more laps. Participants are given a warning if they do not reach the line in time with the signal. The test is stopped when the participant cannot reach the line in time with the audio signal on two consecutive shuttles or if the participant voluntarily stops.

Numerous versions of this test have emerged. The initial version (Léger & Lambert, 1982) was a 20m multistage fitness test which began at 8.5 km/hr and increased by 0.5 km/hr every 2 minutes. Acknowledging that mechanical efficiency of running is proportional to age and that the two-minute stages were boring for children (Astrand, 1952; Daniels, Oldridge, Nagle, & White, 1978; Davies, 1980; MacDougall, Roche, Bar-Or, & Moroz, 1983; Pate, 1981; Silverman & Anderson, 1972), a 1 minute staged version was developed (Léger et al., 1984). This newly designed version which begins at 8.5 km/hr and increases by 0.5 km/hr every minute, is a valid and reliable assessment of CRF (Hamlin et al., 2014; Léger, Merchier, Gadoury, & Lambert, 1988; van Mechelen, Hlobil, & Kemper, 1986). A third protocol validated by Liu, Plowman and Looney (1992) begins at 8.0 km/hr, increases to 9.0 km/hr after one minute and then increases by 0.5 km/hr each subsequent minute. This protocol is used by Eurofit (Council of Europe, 1988), the Australian Coaching Council (Australian Sports Commission, 1999), the British National Coaching Foundation, (Brewer, Ramsbottom, & Williams, 1988), and the American

PACER (Cooper Institute for Aerobics Research, 1992). A fourth protocol, namely The Queen's University of Belfast (Riddoch, 1990) protocol, starts at 8.0 km/hr, and increases in speed by 0.5 km/hr each minute.

Inconsistent reporting of the results of the 20m SRT make it difficult for comparisons between children's CRF levels to be made. For example, some researchers report the number of stages completed while others the number of laps (i.e. stages plus laps), test duration or estimation of VO<sub>2</sub>max (Tomkinson, Léger, Olds, & Cazorla, 2003). Regardless of the protocol used, the 20m SRT has many advantages for use in studies with large sample sizes; it can be administered in a small area, large numbers can be tested at the same time, difficulties with children pacing themselves are avoided (Hamlin et al., 2014) and it provokes a maximal effort in children (Voss & Sandercock, 2009).

The 550m walk/run test (the 600-yard dash) is a test commonly used to measure the CRF of children and adolescents that requires participants to complete a distance of 550m in the quickest time possible. A study that examined the validity of the 550m run/walk test using a sample of 53 children (mean age: 10.6 ± 1.2 years) from New Zealand (Hamlin et al., 2014) reported a significant, moderate correlation ( $r=.59, p<0.05$ ) between the 550m run/walk test and VO<sub>2</sub>max measured using the 2 minute Balke treadmill protocol (Rowland, 1993), indicating that the test is a valid tool for the assessment of CRF among children. Advantages of distance runs such as the 550m walk/run include the ability to test a large number of children over a short time period with little equipment. Results of the 550m walk/run test are likely influenced by motivation, environmental conditions (e.g. underfoot, wind, rain, temperature) and the ability to pace (Hamlin et al., 2014) and consequently it is important to record the status of each of these factors during testing and to keep such factors constant when evaluating CRF across multiple time points. For example, administrators can motivate children by encouraging them to complete the 550m distance (5 x 110m laps) as quickly as possible prior to the commencement of the test and by informing them how many laps they have left on the completion of each 110m lap. Test administrators should ensure that environmental conditions are the same at each time point by conducting

the test in the same place and in similar weather conditions (e.g. on a dry, grass surface on a dry, relatively windless day).

### CRF of Children Worldwide

CRF among children worldwide is declining (Tomkinson et al., 2003; Tomkinson & Olds, 2007; Tremblay et al., 2010, Sandercock et al., 2010). When changes in CRF from 1958-2003 were calculated for children from 27 countries, it was found that there was a global decline in CRF of 0.47% per annum among children (<13 years), with declines of 0.63% per year observed in the latter part of the last century (the 1990s) (Tomkinson & Olds, 2007). The studies included for these calculations used numerous different tests to assess CRF. The tests used were (i) timed distance runs over various different distances (300m, 400m, 402m/¼ mile, 550m, 600m, 800m, 805m/½ mile, 1,000m, 1,200m, 1,207m/¾ mile, 1,500m, 1,600m, 1,609/mile, 2,000m, 2,400m, 2,414/1.5 mile), (ii) tests that measured the distance covered over a specific time (5, 6, 9, 10 or 12 minutes) and (iii) the 20m shuttle run test. On analysis of the secular trend in CRF (from 1991 to 2003) using only 550m run time as the measure of CRF, Albon, Hamlin and Ross (2010) reported annual declines of 1.5% and 1.7% among 10-14 year old New Zealand boys and girls, respectively. While advances in technology, increases in energy-dense foods (French, Story, & Jeffrey, 2001) and reduced running efficiency (Tomkinson et al., 2003) have been suggested as contributing factors to the declining CRF, the decline has been largely attributed to reduced PA levels among youth (Dollman, Norton, & Norton, 2005; French et al., 2001; Tomkinson et al., 2003).

### CRF of Irish Children

In Ireland, there is a limited amount of data relating to the 0) levels of primary school children. The Children's Sport Participation in Physical Activity Study (CSPPA) reported that 23% of Irish 10-18 year olds (mean age: 13.4 ± 2.1 years) were unfit using the 20m SRT (boys and girls were classified as 'unfit' if they had a VO<sub>2</sub>max <42.0 ml/kg/min and <37 ml/kg/min, respectively) (Woods et al., 2010). While this study evaluated the CRF of a representative sample of Irish youth (N=1,215), only 33% of the sample were primary school-aged children. Research presented by Hudson et al. (2015) found that 40.2% of a cohort of Irish 10-12 year olds (N=278) were unfit using the 15m PACER.

Children in this study were classified as unfit if their  $VO_2\text{max} \leq 40.1$  ml/kg/min. While these two investigations used different field tests to assess CRF and used different cut-points to classify children into a fitness category (i.e. fit or unfit), both found that over one in five Irish youth have low fitness levels associated with CVD risk.

#### Sex-Related Differences in CRF

Sex-related differences in CRF have been observed, with research consistently reporting higher CRF levels among boys than girls (Barnett et al., 2018; Dencker et al., 2007; Hamlin et al., 2014; Housby, 1986; Marshall & Bouffard, 1997; Tomkinson et al., 2017). Hamlin et al. (2014) reported that boys demonstrated significantly superior CRF levels compared to girls on both the 20m SRT (Boys:  $42.9 \pm 19.1$  laps, Girls:  $33.4 \pm 16.0$  laps,  $p < 0.05$ ) and 550m run (Boys:  $154.0 \pm 14.4$  secs, Girls:  $168.3 \pm 19.1$  secs,  $p < 0.05$ ). Similarly, Marta, Marinho, Barbosa, Izquierdo, and Margues (2012) who investigated sex-related differences in CRF among prepubescent Portuguese children (N=312, mean age:  $10.8 \pm 0.4$  years), found that boys scored significantly higher on the 20m SRT than their female counterparts (Boys:  $31.05 \pm 1.19$  laps, Girls:  $25.38 \pm 1.05$  laps,  $p < 0.01$ ). While approximately 40% of the variation in CRF is attributable to genetics (Bouchard, 1986), researchers have attributed the superior CRF levels of boys to the greater PA levels demonstrated by boys (Hussey et al., 2007; Woods et al., 2010) and others to body composition differences, with higher fat masses observed among girls (Hamlin et al., 2014). Some suggest that sex-related differences are due to more than differences in PA levels or body composition alone, but a combination of PA levels, body composition, blood haemoglobin concentration and maximal stroke volume (Armstrong & Welsman, 2007). However, Vinet et al. (2003) found no difference in stroke volume between boys and girls, suggesting that stroke volume may not contribute to sex-related differences in CRF among children.

#### Age-Related Differences in CRF

Research suggests that maturation has a significant effect on children's CRF, with improvements with age observed among children up to puberty (Armstrong & Welsman, 1994; Bar-Or, 1983; Housby, 1986; Mirwald & Bailey, 1986). Marshall & Bouffard (1997) found that 9-10 year old children scored significantly better on the 20m SRT (Léger,

Lambert, Goulet, Rowan, & Dinelle, 1984) than 5-6 year old children ( $p < 0.05$ ). Rush et al. (2014) also reported greater CRF levels (measured as time taken to complete 550m) among 9-11 year old children (mean age:  $10.30 \pm 0.51$  years) compared to their younger 6-8 year old counterparts (mean age:  $7.57 \pm 0.58$  years), with the mean 550m time of the 9-11 year old cohort 19 seconds faster than the 6-8 year old group. Regression analysis by Houlsby (1986) found that age predicted 48.1% of the variation in CRF among children, with a larger amount of variation in CRF explained by age among boys (66%) than girls (3.5%). Increases in CRF with age have been attributed to the increase in lung, heart and stroke volumes, total haemoglobin and lean body mass that also occur with age (Haywood & Getchell, 2014).

### FMS and CRF

The relationship between FMS and CRF among children is speculative (Burns et al., 2017). While Robinson et al. (2015) reported that a consistent positive relationship between motor competence and health related physical fitness, it must be noted that the conclusions of the study were drawn when using 'motor competence' as an umbrella term for motor proficiency, motor performance, fundamental movement/motor skill, motor ability, and motor coordination; while 'health related physical fitness' referred to CRF, muscular strength, muscular endurance and flexibility.

A review by Lubans et al. (2010) reported a positive relationship between FMS and CRF. However, only one of the four studies that investigated this relationship measured both FMS proficiency and CRF during the childhood years, and used a process-oriented FMS assessment tool (Marshall & Bouffard, 1997). The research by Marshall and Bouffard (1997) found a moderate, positive correlation ( $r = .48$ ,  $p < 0.05$ ) between FMS proficiency (measured using the TGMD) and CRF (measured using the 20m SRT) among 198 Canadian 5-6 and 9-10 year old children, suggesting that greater FMS proficiency is associated with higher CRF levels. However, the positive relationship between OC skills and CRF was only significant among 5-6 year olds. A study by Haga (2009) carried out among a cohort of 9-10 year old primary school children ( $N = 18$ ), reported that those with low motor competence ( $\leq 5^{\text{th}}$  percentile) recorded lower CRF scores than those with high motor competence ( $60^{\text{th}} - 95^{\text{th}}$  percentile) (Haga, 2009), suggesting that motor



competence is associated with more favourable CRF. However, it must be noted that the sample size in this study was limited.

A more recent systematic review investigating the relationship between motor competence and health related physical fitness in youth by Cattuzzo et al. (2016) also reported a positive relationship between motor competence and CRF. However, only 3 of the 12 studies were conducted among children only and they measured FMS using process-oriented assessment tools (Castelli & Valley, 2007; Haga, 2009; Marshall & Bouffard, 1997). A study involving both elementary and high school children from Australia by Hardy, Réintgen-Reynolds, Espinel, Zask, and Okely (2012) reported that children who demonstrated low motor competency (measured using Get Skilled: Get Active) were more likely to be unfit (classified using FITNESSGRAM standards for the 20m SRT) than their more skilled counterparts. The study reported that boys with low FMS competency were approximately 3-7 times more likely to be unfit than those who were competent, while girls with low FMS competency were approximately 2-6 times more likely to be unfit than their more skilled counterparts. (Children were classified as having low object-control competence if they failed to demonstrate mastery in a minimum of two out of three object-control skills and low locomotor competency if they failed to demonstrate mastery in a minimum of three out of four locomotor skills).

Burns et al. (2017), using the TGMD-3, found a positive relationship between FMS and CRF (measured using the PACER) among children from low-income elementary schools. Among a group of 224 third to 5<sup>th</sup> grade children (mean age:  $9.1 \pm 1.1$  years), a significant small positive relationship was found between LOCO and CRF ( $r=.32, p<0.001$ ). A significant small positive correlation was also found between TGMD-3 total score and CRF ( $r=.28, p<0.001$ ) among this cohort. However, no significant correlation was found between ball skills and CRF ( $r=.18, p<0.05$ ).

A longitudinal study by Barnett, Morgan, van Beurden, and Beard (2008) found that OC proficiency in childhood (7-11 years) was associated with adolescent CRF levels and explained 26% in the variation in adolescent CRF. Furthermore, a longitudinal study by Hands (2008) that involved tracking the fitness of two groups (5-7 years of age at

baseline) of children; one group with development coordination disorder (n=19), and one with high motor competence (n=19), found a significant group by time interaction for the 20m shuttle run test scores over a 5 year period ( $p<0.05$ ). The difference in CRF levels between the two groups increased over time with the low motor competence group performing less well each year on the test than their counterparts in the high motor competence group. These findings suggest that FMS development in childhood is necessary to optimise fitness levels during adolescence, a time associated with high levels of dropout in sport among youth (Berger, O' Reilly, Parent, Séguin, & Hernandez, 2008; Riddoch et al., 2004). Children with low FMS competence are likely to demonstrate poor perceptions of their competence (one of the five most popular reasons identified for dropout among youth) (Crane & Temple, 2015) and a lack of motivation to participate in physical activities. As a result, they may not engage in sufficient MVPA to either enhance CRF or maintain optimal levels of CRF (Cairney, Hay, Faught, Corna, & Flouris, 2006).

#### **2.3.4 Physical Activity (PA)**

PA is defined as any movement of the body that is produced as a result of muscle action and involves energy expenditure (Ortega et al., 2007). PA is often quantified in terms of duration (number of minutes) and intensity (the amount of effort required to carry out the activity) (WHO, 2010). PA is typically classified as light (e.g. casual walking), moderate (e.g. brisk walking, dancing, cycling, jumping on a trampoline) or vigorous (e.g. running, jumping, playing basketball/football) intensity activity (US Department of Health and Human Services, 1999; WHO, 2010). With physical inactivity the fourth leading cause of mortality (Kohl et al., 2012), it is recommended that children aged 5-17 years engage in at least 60 minutes of MVPA every day (Healthy Ireland, 2016; WHO, 2017e). Furthermore, it is recommended that most of this exercise should be aerobic in nature and that vigorous PA, as well as muscle and bone strengthening activities, should be incorporated 3 days each week (WHO, 2017e).

PA is associated with many physical, psychological and mental health benefits among children (Janssen & LeBlanc, 2010; Public Health England, 2017; Strong et al., 2005)

including favourable cardiovascular health, bone health, CRF, academic performance (Haapala et al., 2016). It is also inversely related to adiposity (Ekelund et al., 2004; Patel & Talati, 2016; Rennie et al., 2005; Ruiz, Rizzo, et al., 2006), anxiety and depression. Janssen and LeBlanc (2010) who reviewed the dose-response relationship between PA and health, reported that the more PA one participates in, the greater the health benefit, and highlighted that aerobic-based activities were associated with the greatest health benefits (with the exception of bone health for which weight bearing activities were optimal).

### Measuring PA of Children

Assessing children's PA patterns is challenging due to the sporadic (short and intermittent) nature of their activity (Bailey et al., 1995) as well as their limited cognitive abilities (i.e. their inability to accurately recall and/or their lack of understanding of typically used terminology found in questionnaires) (Kang, Mahar, & Morrow, 2016; Loprinzi & Cardinal, 2011). Methods used to assess PA behaviour include direct observation, self-report (e.g. diaries, questionnaires, proxy reports), objective measures/monitoring (e.g. heart rate monitors, pedometers, accelerometers), direct or indirect calorimetry and the doubly labelled water technique (Kohl, Fulton, & Caspersen, 2000). The two most commonly used methods in epidemiological studies are self-report and objective measures. While self-report measures capture the *perceptions* of what PA has been engaged in, objective measures assess the *actual* quantity (and often the intensity) of the activity (Kang et al., 2016).

Self-report questionnaires typically ask individuals to recall information relating to any PA they participated in over a period of time in the recent past (e.g. the past 7 days) or their usual PA habits (e.g. during a typical week). They are inexpensive, relatively easy and quick to administer, provide information on the type as well as the context of PA and can be used to collect data from a large number of individuals (Loprinzi & Cardinal, 2011). However, PA is often overestimated using self-report measures (Hussey et al., 2007; LeBlanc & Janssen, 2010; Troiano et al., 2008). Further disadvantages of the self-report method of PA assessment include the limited cognitive ability of children to accurately (i) interpret the questions asked and (ii) recall their PA (Kohl et al., 2000; Loprinzi & Cardinal, 2011). The reliability and validity of self-report measures among

youth are questionable. Reviews have reported reliability coefficients ranging from 0.20-0.93 and validity coefficients ranging from 0.03 to 0.88 (Kohl et al., 2000; Sallis, 1991; Sallis & Saelens, 2000), with lower coefficients reported among children than adolescents (Kohl et al., 2000; Loprinzi & Cardinal, 2011; Sallis, Buono, Roby, Micale, & Nelson, 1993). It is recommended that self-report measures of PA should not be used with children younger than 10 years as they cannot accurately nor reliably recall and report their PA at this age (Baranowski, Dworkin, & Cieslik, 1984; Kohl et al., 2000; Saris, 1985). While proxy reports (i.e. parents or teacher's reports of a child's PA) have been suggested as an alternative to self-report among young children (Loprinzi & Cardinal, 2011), further investigation into the reliability and validity is warranted (Sirard & Pate, 2001). A review by Sallis (1991) reported a moderate correlation between proxy reports and activity monitored PA, but no significant relationship with direct observation or heart rate data ( $p>0.05$ ). A study by Sirard and Pate (2001) that reviewed various different PA assessment methods in children and adolescents, reported only three (dated) studies that investigated the validity of proxy-reporting PA methods, with mixed results reported. More recently, among children aged less than 6 years, Sarker et al. (2015) found that parent-reported child PA was only weakly correlated ( $r=.39$ ,  $p<0.01$ ) with objectively measured PA, with a difference of 131 minutes per day of total PA reported between the two measures.

Accelerometry is among the most accurate and practical methods of assessing PA (both quantity and intensity) over a period of time (Kohl et al., 2000; Loprinzi & Cardinal, 2011). Accelerometers are relatively small, lightweight monitors (typically worn at the hip) that record movement in 'counts' of activity (Loprinzi & Cardinal, 2011; Pate, 1993). Activity counts per time-interval (or epoch) are subsequently used to estimate activity intensity (Kohl et al., 2000). Accelerometers have good battery life and adequate storage to record and store activity patterns for several weeks which can then subsequently be downloaded for analysis (Kohl et al., 2000; Loprinzi & Cardinal, 2011). Accelerometers are also more cost effective and practical for measuring PA among a large sample than other methods such as direct observation, calorimetry and doubly labelled water. Accelerometers are reliable and valid PA measurement tools (Kohl et al., 2000) with test-retest reliability coefficients of between 0.61-0.84 (Troutman, Allor, Hartmann, &

Pivarnik, 1999), inter-instrument reliability of between 0.86 and 0.96 (Sallis, Patterson, Morris, Nader, & Buono, 1989) and validity coefficients typically exceeding 0.7 (Loprinzi & Cardinal, 2011; Sirard & Pate, 2001). However, it must be noted that accelerometers cannot be worn in water - therefore aquatic activities cannot be recorded, nor can they accurately quantify activity while cycling with stated validity coefficients between 0.06 and 0.15 reported (Troutman et al., 1999). Further challenges related to accelerometers include wear time compliance among children and the comparability of results. The numerous different protocols in terms of accelerometer type and model, wear time, wear time validation, epoch length, intensity cut-points among others, make it difficult to accurately compare research findings, so much so that it has been acknowledged that a universal standard protocol is required (Banda et al., 2016; Kohl et al., 2000) to allow for consistent measurement of PA that will subsequently guide efforts to promote PA among children.

As each measurement technique has advantages and disadvantages, it has been suggested that researchers should use more than one method to increase the accuracy of PA measurements (Troiano, Pettee Gabriel, Welk, Owen, & Sternfeld, 2012). For example, the use of both accelerometers (objective) and activity diaries (self-report) could provide more accurate information relating to children's PA (e.g. aquatic activities that the accelerometer will not record will be captured in the activity diary) (Ottevaere et al., 2011).

Various different accelerometer types exist. Accelerometers can measure acceleration in one (uni-axial), two (bi-axial) or three (tri-axial) planes of motion (Kohl et al., 2000). As children's PA patterns often involve movement in more than one plane of motion (Loprinzi & Cardinal, 2011), it has been suggested that tri-axial accelerometers may be the most accurate to capture children's PA patterns (Eston, Rowlands, & Ingledew, 1998; Loprinzi & Cardinal, 2011; Louie et al., 1999). Accelerometers designed by ActiGraph are among the most widely used accelerometers in PA research, in particular PA research among children and adolescents (Trost, McIver, & Pate, 2005). Two commonly used models are the ActiGraph GT3X and the ActiGraph GT3X+. Both of these devices are tri-axial (i.e. measure activity in the vertical, medio-lateral and antero-posterior axes),

digitise acceleration output by a 12-bit analog-to-digital converter and store this data for subsequent analysis. Research by Robusto and Trost (2012) reported small to negligible inter-monitor differences for vertical axis counts, vector magnitude and estimated MVPA between these models and thus outlined that a combination of GT3X and GT3X+ activity monitors can be used within the one study.

The traditional placement for accelerometers was at the hip. However, limitations of such placement include hip-worn accelerometer's inability to capture arm movements (Johansson, Larisch, Marcus, & Hagstromer, 2016). Recently researchers have also used other accelerometer placement sites such as the wrist, which has yielded higher wear time compliance among children (Fairclough et al., 2016). In a study carried out among 9-10 year old children (N=129), when wear time validation criteria were set as a minimum of 10 hours per day on at least three weekdays and one weekend, non-compliance was only 16.4% when using wrist-worn GENEActiv accelerometers compared to 25.2% for hip-worn ActiGraph accelerometers. In a study examining children and young people's views on wrist and hip-worn accelerometer wear, it was found that wrist-worn accelerometers were preferred over hip-worn accelerometers (McCann, Knowles, Fairclough, & Graves, 2016). Research has reported that wrist-worn accelerometers are valid and reliable measures of PA among children (Chandler, Brazendale, Beets, & Mealing, 2016; Ekblom, Nyberg, Bak, Ekelund, & Marcus, 2012; Hislop, Palmer, Anand, & Aldin, 2016; Johansson et al., 2016; Trost, Zheng, & Wong, 2014). However, a study by Hilderbrand, van Hees, Hansen, & Ekelund (2014) found that the wrist-worn accelerometers give significantly higher PA output values than hip-worn accelerometers ( $p < 0.01$ ). Furthermore, on comparison of a hip worn ActiGraph accelerometer, a wrist-worn ActiGraph accelerometer, a hip-worn GENEActiv accelerometer and a wrist-worn GENEActiv accelerometer among children, the hip-worn explained the largest proportion of variance in accelerometer output (METs) when compared to the others (Hilderbrand et al. 2014). Furthermore, ActiGraph accelerometers which are the commonly used accelerometers in PA research among children, are traditionally worn on the hip and so much of the existing PA research has reported PA findings from data collected at the hip.

Minutes per day of PA and the percentage of time spent in the various different PA intensities are calculated based on intensity cut-points (Banda et al., 2016). The five most commonly used ActiGraph cut-points developed specifically for use among youth are those of Evenson, Catellier, Gill, Ondrak, and McMurray (2008), Freedson, Pober, and Janz (2005), Mattocks et al. (2007), Puyau, Adolph, Vohra, and Butte (2002) and Treuth et al. (2004) (Table 2.3).

**Table 2.3:** PA cut-points for children

<b>Cut-points</b>	<b>LPA (cpm)</b>	<b>MPA (cpm)</b>	<b>VPA (cpm)</b>
Evenson et al. (2008)	101-2295	2296-4011	≥4012
Freedson et al. (2005)	150-499	500-3999	≥4000
Mattocks et al. (2007)	101-3580	3581-6129	≥6130
Puyau et al. (2002)	800-3199	3200-8199	≥8200
Treuth et al. (2004)	100-2999	3000-5200	≥5201

**cpm**=counts per minute, **LPA**=light PA, **MPA**=moderate PA, **VPA**=vigorous PA

The cut-points of Evenson et al. (2008) were developed in a calibration study involving the measurement of PA data in the vertical axis. Data were collected in 15 second epochs and compared to oxygen consumption values obtained via indirect calorimetry. While the Evenson et al. (2008) cut-points were developed using a sample of 5-8 year old children, a study by Trost, Loprinzi, Moore, and Pfeiffer (2011), compared five different cut-points for predicting activity intensity among 5-15 years olds (N=206) and reported that the intensity cut-points of Evenson et al. (2008) were the most accurate for estimating time spent in PA intensities among children. This study involved participants completing 12 standardised activities (including sedentary, lifestyle and ambulatory activities). Activity trials were 5 minutes in duration (with the exception of the 'lying down' activity which was 10 minutes). Activity counts per minute and VO<sub>2</sub> were measured using ActiGraph GT1M accelerometers and indirect calorimetry respectively. Analysis revealed that only the Evenson et al. (2008) cut-points had acceptable classification accuracy for sedentary time, light PA, moderate PA, vigorous PA for children of all ages.

Epoch length refers to the time interval (seconds) over which activity counts are summed and stored (Sherar et al., 2011). Epoch length has been shown to influence the quantification of children's PA in terms of the duration of time spent at the various

intensities (Aibar & Chanal, 2015; Banda et al., 2016; Loprinzi & Cardinal, 2011), therefore selecting an appropriate epoch length is important to ensure accuracy in measuring PA. As children's PA patterns are sporadic in nature and may last no longer than a few seconds (Baquet, Stratton, van Praagh, & Berthoin, 2007; Ward, Evenson, Vaughn, Rodgers, and Troiano, 2005), long epoch lengths (e.g. 1 minute epochs) may underestimate the time children spend at higher intensities (i.e. moderate PA, vigorous PA and MVPA) (Banda et al., 2016; Edwardson & Gorely, 2010; Nilsson, Ekelund, Yngve, & Sjostrom, 2002) and overestimate the time spent in lower intensities (sedentary behaviour and light PA) (Banda et al., 2016; Colley, Harvey, Grattan, & Adamo, 2014; Gabriel et al., 2010). A study by Vale, Santos, Silva, Sowres-Miranda, and Mota (2009), that assessed the PA level of 2-5 year old children (N=59) during the school day using 5- and 60-second epochs, reported a significant 16.4 minute (62%) difference in MVPA between the two epoch lengths ( $p<0.01$ ). A total of  $26.46 \pm 9.64$  minutes MVPA were reported when the 5-second epoch was applied to the data, while only  $10.05 \pm 8.43$  minutes MVPA were recorded using the 60-second epoch (Vale et al., 2009). McClain, Abraham, Brusseau, and Tudor-Locke (2008), who compared the PA level of 5<sup>th</sup> grade USA children (N = 32: mean age:  $10.3 \pm 0.5$  years) during a 30-minute PE class using different accelerometer epochs to that measured via direct observation, found that a 5-second epoch was the most accurate for measuring children's MVPA when compared to longer epochs of 10, 15, 20, 30 and 60 seconds.

The number of days that participants need to wear an accelerometer for, so that an accurate measure of habitual PA can be obtained, has been examined by Trost, Pate, Freedson, Sallis, and Taylor (2000). It was revealed that 7-day accelerometer monitoring is reliable for estimating the PA patterns of children (ICC = 0.86-0.87) as it accounts for potentially important differences across days, especially weekend versus weekdays. While the study highlighted that a minimum of 4-5 days of activity monitoring would be necessary to ensure reliability of 0.8, and 9-11 days of monitoring would be required for reliability of 0.9, 7-day monitoring was pragmatically recommended for use among children (Welk, 2005).



While children are typically instructed to wear the accelerometer distributed to them for all waking hours of the 7 consecutive days they have them, compliance is often an issue. Because of this struggle with compliance, a set of minimum criteria for inclusion in data analysis is usually outlined by researchers. Some researchers have set their inclusion criteria at as little as one full day (Matthews et al., 2008; Treuth et al., 2007). However, the reliability of one day monitoring among children has been found to range from 0.46-0.49 (Troost et al., 2000). With reliabilities of 0.7, 0.8 and 0.9 requiring data monitoring for 2-3, 4-5 and 9-11 days (Troost et al., 2000), other researchers have chosen inclusion criteria that require more days of wear time. Sirard, Kubik, Fulkerson, and Arcan (2008) and Troiano et al. (2008) set their requirements for inclusion at 4 full days, while Ekelund et al. (2004), Masse et al. (2005) and Riddoch et al. (2007) set their inclusion criteria as 3 full days of accelerometer wear time. A study by Mattocks et al. (2008) that was conducted among 11 year old children (N=5,595) provided support for these requirements as the study revealed that a protocol requiring 3 days of at least 10 hours per day of recording, had adequate reliability (0.7) and power (>90%) for the measurement of PA via accelerometry.

Inconsistent findings have been reported for the difference between weekday and weekend PA among children. Some researchers have reported no difference in the PA level of children between weekday and weekend days (Mattocks et al., 2008; Steele et al., 2010; Troiano et al., 2008) and thus some inclusion criteria consist of no specific requirements relating to the number of weekend days and hours (e.g. Mattocks et al. 2008). However, other researchers have found differences between children's weekday and weekend PA levels (Burgi & de Bruin, 2016; Rowlands & Eston, 2007; Troost et al., 2000), and consequently require a sufficient amount of weekend as well as weekday PA for inclusion in any data analysis process. For example, Riddoch et al. (2004) require 4 full days of monitoring, one of which must be a weekend day. While protocols may vary from study to study, a review by Cain, Sallis, Conway, van Dyck, and Calhoon (2013) outlined that the 'rough consensus' for PA data collection is a monitoring period of 7 days, with a minimum of 4 valid days (including at least one weekend day), required to be included in data analysis.

While it is recommended that accelerometers are worn for a minimum of 10 hours per day among youth (Macfarlane, Lee, Ho, Chan, & Chan, 2006; Penpraze et al., 2006), a review by Cain et al. (2013) found that in studies measuring PA patterns of children and adolescents, the number of hours required for valid wear time ranged from 6 hours to 10 hours.

'Non-wear time' aims to identify periods of time during which an accelerometer is not worn. Strings of consecutive zero counts per minute indicate that the accelerometer has been removed. However, a string of zeros will also be recorded if the participant engages in a sedentary activity for a period of time. In an attempt to accurately distinguish between these two occurrences, a number of definitions of non-wear time have been used. A review of 273 studies by Cain et al. (2013) identified five different definitions of 'non-wear time' that had been applied to PA data collected from children. These were periods of 10, 15, 20, 30 and 60 minutes of consecutive zeros. Of the five identified definitions, 10- and 20-minute periods of consecutive zeros were the most commonly applied in PA research among youth (Cain et al., 2013).

### Levels of PA

PA levels worldwide are decreasing, with declines ranging from 2.3% (measured from 2000 to 2005 in Brazil) to 44.9% (measured across the 18 year period from 1991 to 2009 in China) reported (Ng & Popkin, 2012). Furthermore, declines of 32.2% and 20.2% were observed in the USA and UK between the 1960s and 2000s. While these trends reported by Ng and Popkin (2012) were observed using data collected from individuals over 18 years of age, declines in PA among children and adolescents have also been reported (Fuller, Mindell, & Prior, 2016; Woods et al., 2010). The Health Survey for England (NHS Digital, 2016) reported a 2% decline in the proportion of 5-15 year olds reaching the daily 60 minute MVPA guideline between 2008 and 2015 (24% and 22% met this recommendation in 2008 and 2015, respectively). However, this data was collected via interview, with different cohorts evaluated at each time point.

In Ireland, the proportion of 10-13 year old primary school children meeting the recommended 60 minutes MVPA daily in 2009 was 19%. This figure decreased by 1%

from 2004 when one in five Irish primary school children engaged in at least 60 minutes of MVPA per day (Woods et al., 2010). While the majority of data relating to PA levels of Irish youth were recorded via self-report methods (Hardie Murphy, Rowe, & Woods, 2016; Kelly, Gavin, Molcho, & Nic Ghabhainn, 2012; Thornton, Williams, McCrory, Murray, & Quail, 2016; WHO, 2012; J. Williams et al., 2009; Woods et al., 2010), one study that collected PA data using accelerometers among a cohort children from Cork found that only 22% of 8-11 year olds (N=830) met the PA guidelines (Keane, Kearney, Perry, Browne, & Harrington, 2014). The amount of research that has collected valid and reliable accelerometer-based data among children is limited in Irish context. Belton, Brady, Meegan, and Woods (2010), who used an alternative objective measure of PA (pedometers), found that 62.5% of 6-9 year olds from four mixed-sex primary schools in Dublin (N=301) met the age- and sex-specific BMI referenced pedometer cut points (15,000 steps per day for boys and 12,000 steps per day for girls) (Tudor-Locke et al., 2004). However, neither the number of minutes spent in MVPA nor the proportion of children meeting the 60 minutes MVPA guideline were estimated from the data collected.

It has been reported that children accumulate more MVPA on weekdays compared to weekend days (Burgi & de Bruin, 2016; Comte et al., 2013; Kettner et al., 2013; Nilsson et al., 2009). Kettner et al. (2013) reported that primary school children (N=384) from south-west Germany accumulated more MVPA on weekdays ( $144 \pm 66$  min/day) than weekend days ( $113 \pm 66$  min/day). Similar results were reported among a 10-15 year old cohort from Canada with approximately 30% less MVPA accumulated by children at weekends compared to weekdays (Comte et al., 2013). In contrast, the only study that has compared between day PA levels among Irish children found that 6-9 year old children (N=201) from four mixed-sex schools in Dublin, were significantly more active at the weekends compared to weekdays ( $p < 0.01$ ) (Belton et al., 2010). As PA levels were measured using pedometers in this study, overall PA levels as opposed to MVPA levels were reported and may explain the contrasting results to the previously presented studies who reported MVPA levels. The reports of Belton et al. (2010) support findings by Nilsson et al. (2009) who found that 9 year old Portuguese children (n=292) engaged in more PA (but less MVPA) at weekends compared to weekdays. However, they

contrast findings among children from Denmark (n=301) and Norway (n=292), who engaged in more overall PA (and MVPA) on weekdays, with no between-day difference observed among Estonian children (n=299) (Nilsson et al., 2009).

#### Sex-Related Differences in PA

Worldwide research indicates that boys tend to be more physically active than girls (Ekelund et al., 2012; Haapala et al., 2016; Hallal et al., 2012; Ishii, Shibata, Adachi, Nonoue, & Oka, 2015; Pearce et al., 2012; Sallis, Prochaska, & Taylor, 2000; Telford, Telford, Olive, Cochrane, & Davey, 2016; Trost et al., 2002; van der Horst, Paw, Twisk, & van Mechelen, 2007). Telford, Telford, Olive, et al. (2016), among 8 year old Australian children (N=555), found that girls accumulated 19% less steps per day than boys (Boys: 12256 ± 1876 steps/day, Girls: 9900 ± 1701 steps/day,  $p < 0.01$ ). This trend was also apparent among this cohort at 12 years (N=361), when girls were again found to have taken significantly fewer steps per day than their male counterparts (Boys: 10,463 ± 3423 steps/day, Girls: 8940 ± 2611 steps/day,  $p < 0.01$ ) (Telford, Telford, Olive, et al., 2016). De Meester et al. (2016), who measured the PA level of a cohort of children from Ohio, Texas and Michigan (N = 361, mean age: 9.49 ± 1.24 years), also found that boys were significantly more active than girls, with boys engaging in more MVPA than girls (Boys: 48.17 ± 25.91 mins/day, Girls: 33.95 ± 16.27 mins/day,  $p < 0.01$ ), with a greater proportion of boys (23.27%) achieving the recommended 60 minutes of daily MVPA when compared to their female counterparts (9.52%).

A disparity in PA patterns between boys and girls has also been found among Irish children (Belton et al., 2010; Kelly et al., 2012; Woods et al., 2010) with research reporting that only 13% of primary school girls met the PA guidelines (60 minutes MVPA daily) while 27% of their male counterparts met this recommendation (Woods et al., 2010). Belton et al. (2010), who used pedometers to assess the PA patterns of 6-9 year old Dublin children (N=301), found that boys took significantly more steps than their female counterparts for the total week, on weekdays and during school time ( $p < 0.05$ ) (Belton et al., 2010).

The differences in PA levels between boys and girls may be due to a number of factors including lower perceived competence, less parental support for PA, lower motor competence and lower CRF among girls compared to boys (Telford, Telford, Olive, et al., 2016). Lower levels of participation in organised (Basterfield et al., 2014; Telford, Telford, Olive, et al., 2016; Vella, Cliff, & Okely, 2014) and extracurricular sport (Telford, Telford, Olive, et al., 2016) that is observed among girls than boys may also explain sex differences in PA levels among children. In Ireland, the greater variety of sporting opportunities and larger availability of resources available for boys than girls (Woods et al., 2010), is also likely to contribute to higher PA levels of Irish boys compared to their female counterparts.

#### Age-Related Differences in PA

Longitudinal studies have reported low to moderate tracking of PA with age (N. Anderssen, Wold, & Torsheim, 2005; Hardie Murphy, Rowe, & Woods, 2016; Perkins, Jacobs, Barber, & Eccles, 2004; Telama et al., 2014). Age differences in PA levels have been found with older children demonstrating lower levels than their younger counterparts (Hardie Murphy et al., 2016; Public Health England, 2017; Telford, Telford, Olive, et al., 2016; Woods et al., 2010). Ishil et al. (2015) found that when 3-15 year old Japanese children were categorised into four school grade-based categories (pre-school, lower grade elementary school, higher grade elementary school and high school), children from the higher grades engaged in significantly less light PA, moderate PA, vigorous PA and accumulated significantly fewer steps per day than their counterparts from the younger grades ( $p < 0.01$ ). While these findings highlight the lower levels of PA among older children, there was no indication as to which cohort(s) were being referred to i.e. high school only, or high school and higher grade elementary school). Among the elementary school cohort, Ishil et al. (2015) found that a smaller proportion of higher grade elementary students (75%) met the PA recommendations than those from lower grades (86.4%). Furthermore, Public Health England (2017) have recently reported that the number of children engaging in the recommended daily 60 minutes of MVPA, decreases by 40% as they move through their primary school years.

In Ireland, a longitudinal study (CSPPA-Plus) assessed the change in PA levels of children over a five year period (Hardie Murphy et al., 2016). The study found that in 2009, 15.2% of boys (mean age:  $11.2 \pm 0.5$  years) and 10.6% of girls (mean age:  $11.2 \pm 0.5$  years) met the PA guidelines. When data was collected five years later from a subset of this original cohort, it was found that 10.6% of males and 7.3% of females met the PA guidelines, demonstrating the decline in PA with age. While these studies highlight the decline in PA from childhood into early adolescence, a longitudinal study by Farooq et al. (2017) found that PA declines from the age of 7 years. This study that was carried out among a socioeconomically representative sample from north-east England involved the collection of PA data (via accelerometers) from children at the ages of 7 (N=431), 9 (N=428), 12 (N=385) and 15 (N=278) years. Group-based modelling of the longitudinal data was used to identify trajectories of age-related patterns in total PA and MVPA. Results revealed declines in both measures of PA began at the age of 7 and continued across the 8 year period over which data were collected (for both boys and girls). While this study examined the trends in PA from the age of 7 to 15 years, reporting declines from the earliest age at which data were collected, others have reported declining PA levels from as early as the time of school entry (Cooper et al., 2015; Kwon, Janz, Letuchy, Burns, & Leby, 2015; Tanaka, Reilly, & Huang, 2014).

### FMS and PA

A review by Logan, Webster, Getchell, Pfeiffer, and Robinson (2015) reported a positive relationship between FMS and PA. However, only one of the 13 studies (Raudsepp & Päll, 2006) included in the review was conducted among a European cohort. This study by Raudsepp and Pall (2006) that was carried out among 133 Estonian elementary school children (mean age:  $7.6 \pm 0.5$  years) investigated the relationship between the developmental level of two FMS (the overarm throw and standing long-jump) and after-school PA, and reported a weak but significant correlation ( $r=.21, p<0.05$ ) between the overarm throw and objectively measured after-school PA, while no significant correlation was reported between the standing long jump and objectively measured after-school PA ( $r=.15, p>0.05$ ). A review by Lubans et al. (2010) that examined the health benefits associated with FMS among children and adolescents also reported a positive relationship between FMS and PA. Over 90% (12/13) of the studies that

evaluated the relationship between FMS and PA that were included in the study reported a significant association between FMS and at least one PA variable (e.g. non-organised PA, organised PA). However, the majority of these studies assessed PA using self-report measures, which are limited by children's cognitive capacity to understand the terminology used in the questionnaires as well as their ability to accurately recall and report their past PA behaviours.

Studies that have investigated the relationship between FMS and PA via objective measures of PA have produced mixed findings (Barnett, Ridgers, & Salmon, 2015; Cohen et al., 2014; Hume et al., 2008). Cohen et al. (2014) reported that among children from low-income communities (mean age:  $8.5 \pm 0.6$  years), object-control proficiency was positively related to daily MVPA ( $r=.20$ ,  $p<0.01$ ). However, no correlation was found between locomotor skill proficiency and daily MVPA ( $r=.15$ ,  $p<0.01$ ). Mixed findings were also reported among Filipino children ( $N=32$ , mean age:  $6.5 \pm 2.45$  years) as FMS proficiency was related to PA during weekend days ( $r=.44$ ,  $p<0.01$ ), but not weekdays ( $r=.16$ ,  $p>0.05$ ) (Capiro, Sit, Eguia, & Abernethy, 2014). De Meester et al. (2018) reported that FMS proficiency was a significant predictor of the proportion of children meeting the PA guidelines of 60 minutes MVPA daily ( $p<0.01$ ). The study revealed that a mere 11% of children who demonstrated low FMS proficiency (<27<sup>th</sup> percentile when compared to normative TGMD-2 data (Ulrich, 2000)) met the PA guidelines, while children with high FMS proficiency (>65<sup>th</sup> percentile) were almost 2.5 times more likely to meet the PA guidelines than their counterparts with low FMS proficiency.

To date, only one study has investigated the relationship between FMS proficiency and weekday/weekend PA among pre-school children (Foweather et al., 2015). The study, among 99 English children (mean age:  $4.6 \pm 0.5$  years) living in deprived communities, found that overall FMS score (measured using the Children's Activity and Movement in Preschool Study Motor Skills Protocol) (H. G. Williams et al., 2008) was positively associated with weekend MVPA ( $\beta=0.6$ ,  $p<0.05$ ) but not weekday MVPA ( $\beta=0.4$ ,  $p>0.05$ ).

While a large limited amount of research has investigated the relationship between FMS and PA, there is a dearth of research examining the relationship between FMS and

different levels of PA (Foweather et al., 2015; Gu, 2016; Hume et al., 2008). Gu's (2016) study of 256 socioeconomically disadvantaged USA primary school children (mean age:  $5.37 \pm 0.48$  years) investigated the relationship between FMS (the combined score from the dribble, hop, slide and throw assessed by the kindergarten level of the PE Metrics; (National Association for Sport & Physical Education, 2010) and objectively measured school-day PA. The study found a significant (albeit weak), positive correlation between FMS and school-day MVPA ( $r=.26, p<0.01$ ) and between FMS and school-day vigorous PA ( $r=.22, p<0.01$ ). Hume et al. (2008), among a sample of 9-11 year old Australian children (N=248) found significant, weak correlations between FMS and vigorous PA (Boys  $r=.25, p<0.05$ , Girls  $r=.21, p<0.05$ ). Hume et al. (2008) also found significant, weak correlations between FMS and MVPA ( $r=.24, p<0.01$ ), and FMS and moderate PA ( $r=.21, p<0.01$ ) among boys. However, no significant relationships between FMS and moderate or vigorous PA were reported among girls ( $p>0.05$ ).

In contrast to research reporting a positive relationship between FMS and PA (Capio et al., 2014; Cohen et al., 2014; Lubans et al., 2010), Cliff et al. (2009) found that among girls, proficiency in locomotor skills was negatively correlated with the percentage of time in MVPA ( $r=-.50, p<0.05$ ). Other researchers have reported no significant relationship between FMS and PA ( $p>0.05$ ) (Barnett, Ridger & Salmon, 2015; McKenzie et al., 2002). Barnett, Ridgers, and Salmon (2015) found that among 4-8 year old children (N=102), object-control proficiency was not associated with MVPA ( $p>0.05$ ), while McKenzie et al. (2002) found no significant relationship between childhood FMS proficiency and PA measured 6 years later ( $p>0.05$ ).

While research investigating the relationship between FMS and PA among children has produced some mixed findings, the general research consensus on the relationship as reported by Robinson et al. (2015) is that a positive relationship exists between FMS and PA, suggesting that the development of FMS has the potential to improve PA levels among children. While much research has examined the relationship between FMS and PA using self-report measures of PA, more research using objective measures of PA and the evaluation of different intensities and across different time periods during the week (e.g. in-school PA, out-of-school PA, weekday, weekend day) is warranted.



## 2.4 Perceived Competence

Perceived competence has been identified as a mediating factor in the relationship between FMS and PA, and FMS and CRF and thus is an important factor to consider in reviewing the FMS proficiency and markers of health of children. This section provides an overview of perceived competence, assessment tools that are commonly used to assess children's perceived competence, benefits associated with it and also the current levels of perceived competence among children. The relationship between (i) perceived competence and PA and (ii) perceived competence and actual FMS competence, are discussed.

### Measuring Perceived Competence

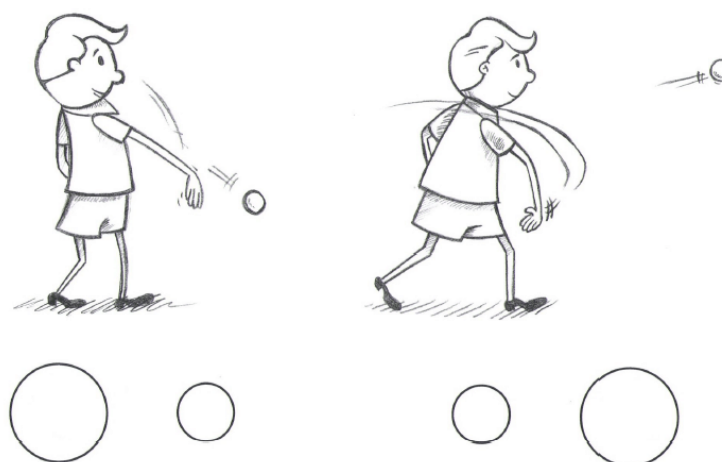
Perceived skill competence (subsequently referred to as perceived competence) is an individual's belief relating to their actual skill ability (Harter, 1999). Measuring perceived competence is important as it provides a greater understanding of how children view their ability levels and may assist the development and delivery of effective PA programmes (Robinson, 2011). Establishing high perceived competence levels among youth is critical for PA participation (Crane & Temple, 2015). The majority of research that has examined the relationship between children's actual and perceived competence has done so using generic or 'non-aligned' measures of perceived competence. In this evaluation process, the questions regarding their perceived competence related to activities different from those which were used in the assessment of actual competence (Babic et al., 2014; LeGear et al., 2012; Robinson, 2011). Furthermore, such generic tools make it difficult to determine whether children have a global perception of physical competence or whether they perceive their locomotor and object-control abilities differently (Liong, Ridgers, & Barnett, 2015). In an attempt to overcome the limitations of using non-aligned tools, researchers have developed perceived competence measurement tools that measure the perceived competence of children in skills that can also actually be assessed using existing FMS assessment tools (Barnett, Ridgers, Zask, & Salmon, 2015; McGrane, Belton, Powell, Woods, & Issartel, 2016; Nobre, Bandeira, & Valentini, 2016). Aligned tools have been

recommended for the evaluation of children's perceived competence (Liong et al., 2015).

The Pictorial Scale of Perceived Competence and Social Acceptance for Young Children (Harter & Pike, 1984) measures the self-perceptions of children from pre-school to second grade (4-8 years) across four domains: (i) perceived physical competence (ii) perceived cognitive competence (iii) peer acceptance and (iv) maternal acceptance. The instrument assesses perceived physical competence in relation to typical childhood activities (running, hopping, swinging on a swing, climbing, tying shoelaces and skipping), and does not assess FMS. It should be noted that the physical competence subscale for children in first and second grades (6 and 7 year olds) assesses only one object-control related skill while the subscale for children of pre-school/kindergarten age (4 and 5 year olds) does not assess any object-control skills. The physical competence subscale from the instrument has been commonly used to assess children's perceived physical competence (Robinson, 2011) and scores from the physical competence subscale range from 6 to 24. The 6-item questionnaire is presented pictorially with children of the same sex and race used in the pictures. Each question presents two pictures; one of a child demonstrating competency in the given task and the other not. The child firstly identifies the child they feel they are more like. The child then decides if they are 'a little like' the child in the picture selected or 'a lot like them'. Acceptable internal consistency (0.86) and reliability (0.89) has been reported for the perceived physical competence subscale (Harter, 1985).

The Pictorial Scale of Perceived Movement Skill Competence (Barnett, Ridgers, Zask, et al., 2015) is a pictorial instrument, designed and modified from the Pictorial Scale of Perceived Competence and Social Acceptance for Young Children (Harter & Pike, 1984) that has been used to evaluate the perceived FMS competence of children (Barnett, Ridgers, & Salmon, 2015; Liong et al., 2015). The tool assesses the 6 locomotor (run, leap, hop, gallop, slide, horizontal jump) and 6 object-control (catch, overarm throw, roll, two-handed strike, kick, stationary dribble) skills of the TGMD-2 (Ulrich, 2000). Similar to the Pictorial Scale of Perceived Competence and Acceptance for Young Children (Harter & Pike, 1984), children are presented with cartoon illustrations of two

children, one 'pretty good' at the given skill, and one 'not so good' (Figure 2.4). Children are asked to identify which child they are more like. Subsequently they are then asked further questions. If they feel they are competent, they are asked are they 'really good' or 'sort of good' at the given skill. If they feel they are not competent, they are asked whether they feel they are 'not that good' or 'sort of good' at the skill. Scores for each question range from one to four (1= not too good, 2=sort of good, 3=pretty good, 4=really good), with total perceived FMS score ranging from 12-48 and perceived locomotor and object-control competence range from 6-24 respectively).



**Figure 2.4:** Images from the Pictorial Scale of Perceived Movement Skill Competence (Barnett, Ridgers, Zask, et al., 2015) used to assess their perceived competence in the throw

The instrument has demonstrated acceptable face validity, good test-retest reliability (object control ICC = 0.78, locomotor ICC = 0.82, and all 12 skills ICC = 0.83) and internal consistency (alpha range = 0.60–0.81) among Australian children (Barnett, Robinson, Webster, & Ridgers, 2015). A further study by Barnett, Robinson, et al. (2015), among a culturally diverse sample of Australian children (n=111) and a racially diverse and socioeconomically disadvantaged sample of American children (n=110), reported acceptable internal consistency among both groups (ranging from 0.66-0.75).

The Self-Perception Profile for Children (SPPC) (Harter, 1985; 2012) is a commonly used instrument that was designed to assess the (i) scholastic competence, (ii) social

acceptance, (iii) athletic competence, (iv) physical appearance, (v) behavioural conduct and (vi) global self-worth of children aged 8 years or older. The athletic competence subscale assesses a child's perceptions of their competence in sports and outdoor activities and games. The SPCC was originally standardised on four samples of greater than 1,500 American school children from third (8-9 years old) to 8<sup>th</sup> grade (13-14 years old). The SPPC is a reliable (internal consistency:  $0.71 \leq r \leq 0.91$  for the different subscales) and valid tool for the measurement of children's self-perception (Muris, Meesters, & Fijen, 2003). The athletic competence subscale of the SPPC has 6 items and has previously been used to assess children's perceived physical/movement competence (Bardid, De Meester, et al., 2016; De Meester et al., 2016). The tool presents children with statements, the beginning of which indicates competence in the given task and the end indicating a lack of competence (e.g. "*some kids do very well at all kinds of sports but other kids don't feel that they are very good when it comes to sports*"). Having picked which part of the sentence is true for them, the child then picks whether the selected part of the sentence is "*really true*" or "*sort of true*" for them. A score between one and four is given depending on the answer (1=lowest competence, 4=highest competence). The mean of the 6 items is usually calculated with final scores ranging from one to four (Harter, 2012).

Both the Pictorial Scale of Perceived Competence and Social Acceptance for Young Children (Harter & Pike, 1984) and the Self-Perception Profile for Children (Harter, 1985; 2012) are limited for use in the examination of the relationship between children's perceived and actual competence as these are both non-aligned tools, i.e. the skills assessed using these tools are not the same skills that are assessed in any of the existing tools used to assess actual competence. In contrast, the Pictorial Scale of Perceived Movement Skill Competence (Barnett, Ridgers, Zask, et al., 2015) is an aligned tool as it assesses the same skills that are assessed using the TGMD-2 (Ulrich, 2000) and therefore should be used in the examination of the relationship between perceived and actual FMS competence among children. This tool has also been widely used which enables comparisons to be made between studies.

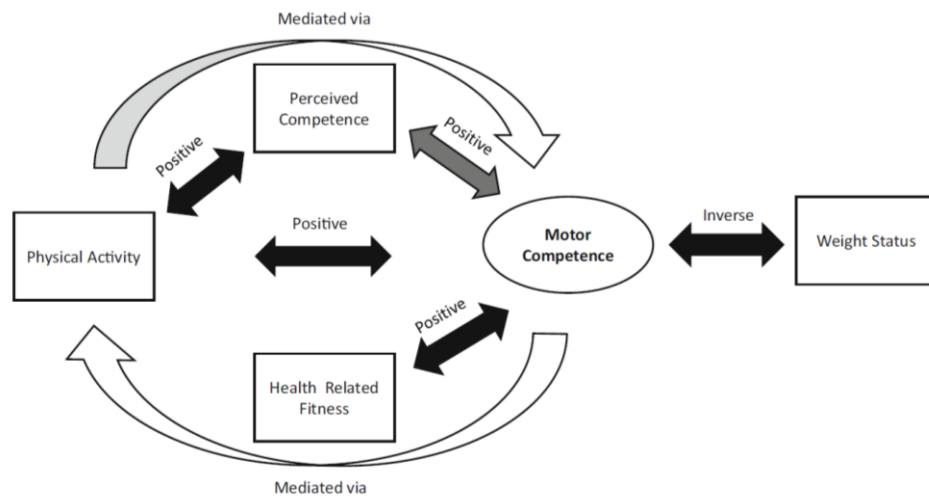
### Perceived Competence and Health

Perceived competence is negatively associated with BMI among children (De Meester et al., 2016; Spessato, Gabbard, Robinson, et al., 2013), with significantly lower perceived competence levels reported among obese children when compared to their normal weight peers (Spessato, Gabbard, Robinson, et al., 2013; Sung, Yu, So, Lam, & Hau, 2005). Perceived competence is positively associated with aerobic fitness (Khodaverdi et al., 2013), self-esteem (Weiss & Amorose, 2005), motivation (Bardid, De Meester, et al., 2016; Ferrer-Caja & Weiss, 2000; Papaioannou, 1997), global self-worth (Bardid, De Meester, et al., 2016) and enjoyment of PE (Carroll & Loumidis, 2001). Some researchers suggest that perceived competence may be more important than actual competence for global self-worth (Bardid, De Meester, et al., 2016), motivation (Bardid, De Meester, et al., 2016; Harter, 1987) and PA (Welk, 1999), while Slykerman, Ridgers, Stevenson, and Barnett (2016) suggest that actual competence may be more important than perceived competence for MVPA. Despite these reports, it is believed that high levels of both actual and perceived competence among children is the optimal position (De Meester et al., 2016; Robinson et al., 2015; Stodden et al., 2008).

Robinson et al.'s (2015) model (Figure 2.5) outlines what they have found to be the general research consensus on the nature of the relationships between motor competence and various markers of health (following a review of relevant literature). The model indicates that a bi-directional relationship exists between motor competence (an umbrella term used to describe goal-directed human performance such as fundamental movement/motor skill, motor ability, motor proficiency, motor performance, fundamental, motor ability, and motor coordination) and PA as this relationship has been extensively tested, and a consistent positive relationship identified.

The model also indicates an indirect bi-directional relationship between motor competence and PA through an individual's perception of their competence, i.e. that perceived motor competence mediates (or brings about) the relationship between FMS and PA, and PA and FMS. While Robinson et al. (2015) outline that this relationship has only been partially tested, supporting evidence has been found

(Barnett, Morgan, et al., 2008; Barnett, Morgan, van Beurden, Ball, & Lubans, 2011; Khodaverdi, Bahram, Stodden, & Kazemnejad, 2016). Khodaverdi et al. (2016) found that among 8-9 year old Iranian girls (N=352), perceived competence and aerobic fitness mediated the relationship between locomotor skill competence and PA with the overall model explaining 58% of the variance in PA (i.e. children's locomotor skill competence, when complemented with their level of aerobic fitness and their perceived competence level, resulted in an increase in their PA level). Barnett, Morgan, et al. (2008) found that perceived competence mediated the relationship between children's object-control (OC) competence and their adolescent PA and CRF, measured 6 years later (with the models explaining 18% and 30% of the variance in PA and CRF respectively). Additional support for the role of perceived competence as a mediating variable in the FMS-PA relationship was reported by Barnett et al. (2011) who found that among adolescents (mean age:  $16.4 \pm 0.6$  years), perceived competence partially mediated the relationship between OC and PA (in both directions) and fully mediated the relationship between PA and locomotor skill competence (when locomotor skill was the outcome variable). In contrast, Cohen, Morgan, Plotnikoff, Barnett, and Lubans (2015) found that perceived competence did not act as a mediating factor of the SCORES intervention (that aimed to improve children's FMS and PA) with regard to both PA or CRF among children from low-income communities. It should be noted that the SCORES intervention evaluated perceived competence using Harter's self-perception profile (Harter, 1985), which is a non-aligned perceived competence tool, i.e. the skills used to measure children's actual FMS proficiency were not the same skills used to assess their perceived competence. Future research should investigate the mediating role of perceived competence using aligned measures (e.g. the TGMD-2 (Ulrich, 2000) and the Pictorial Scale of Perceived Movement Skill Competence) (Barnett, Ridgers, Zask, et al., 2015).



**Figure 2.5:** The relationship between motor competence and health-related variables (Robinson et al., 2015)

### Perceived Competence and PA

It has been proposed that children with higher levels of actual motor competence will also have higher perceived competence, will find movement-related activities less difficult than their less skilled counterparts and as a result will have higher levels of habitual PA (Harter, 1987; Stodden et al., 2008). It has been found that perceived competence is a determinant of PA in children and adolescents (Babic et al., 2014). Several cross-sectional studies among children have reported findings that suggest that a positive relationship exists between perceived competence and PA (Carroll & Loumidis, 2001; De Meester et al., 2016). De Meester et al. (2016), among a cohort of 361 children (mean age:  $9.5 \pm 1.54$  years), found that when children were categorised into three different clusters based on actual and perceived competence levels: high-high (high actual and high perceived), low-high (low actual and high perceived) and low-low (low actual and low perceived) groups, those in the high-high group engaged in significantly more MVPA (48.39 minutes/day) than those with in the low-low (37.93 minutes/day) and low-high (36.21 minutes/day) groups ( $p < 0.01$ ), suggesting that high levels of both actual and perceived competence are important for PA participation. However, in contrast, the study also reported that there was no significant correlation ( $r = .17, p < 0.01$ ) between perceived motor competence and objectively measured MVPA. A longitudinal study among 11-15 year old Scottish children found that those with high perceived competence in their final primary school year were 2.5-3.8 times more likely

to be active in their second and fourth year of secondary school than if they had low perceived competence (Inchley, Kirby, & Currie, 2011), suggesting that establishing a high perceived competence in childhood is important for subsequent PA levels.

In contrast to studies that have reported a positive relationship between perceived competence and PA, others using various different perceived competence assessment tools have also reported no significant association between perceived competence and MVPA among children (Barnett, Ridgers, & Salmon, 2015; Morgan, Okely, Cliff, Jones, & Baur, 2008; Robinson, 2011; Slykerman et al., 2016). Barnett, Ridgers, and Salmon (2015) found that perceived OC skill competence measured using the Pictorial Scale of Perceived Movement Skill Competence was not a significant predictor of MVPA among 4-8 year old Australian children (N=102) ( $p>0.05$ ). Similarly, Slykerman et al. (2016), using the same perceived competence assessment tool, found that neither perceived OC competence nor perceived LOCO competence predicted MVPA among 5-8 year old Australian children (N=109) ( $p>0.05$ ). Barnett, Salmon, and Hesketh (2016) also found no significant relationship between children's perceived competence and PA at age 5 ( $p>0.05$ ). However, they did find that time spent in MVPA at 3.5 years of age predicted perceived competence at the age of 5 years ( $p<0.05$ ).

These studies that have reported no significant relationship between perceived competence and PA (Barnett, Ridgers, & Salmon, 2015; Morgan, Okely, Cliff, Jones, & Baur, 2008; Robinson, 2011; Slykerman et al., 2016) were carried out among young children (<8 years) while those that found a significant, positive relationship were carried out among older children, suggesting that perceived competence may become more important for children's participation in PA as they age.

#### FMS and Perceived Competence

The relationship between actual and perceived movement competence has been assessed using non-aligned and aligned assessment tools. Studies that have used non-aligned tools have reported mixed results (Goodway & Rudisill, 1997; LeGear et al., 2012; Robinson, 2011; Spessato, Gabbard, Robinson, et al., 2013). Significant positive correlations ( $r$  range: 0.20-0.48,  $p<0.05$ ) between FMS and perceived physical



competence have been reported by Robinson (2011), LeGear et al. (2012) and De Meester et al. (2016) among American pre-school children (N=119, mean age: 4.00 ± 0.55 years), Canadian kindergarteners (N=260, mean age: 5.75 years) and American primary school children (N=361, mean age: 9.49 ± 1.24 years), respectively. FMS proficiency in all three of these studies was measured using the TGMD-2 while perceived physical competence was measured using either the physical competence subscale of the Pictorial Scale of Perceived Competence and Social Acceptance for Young Children (LeGear et al., 2012; Robinson, 2011) or the athletic competence subscale the Self-Perception Profile for Children (De Meester et al., 2016). In contrast, a study by Goodway and Rudisill (1997) of 59 African American pre-school children (mean age: 4.75 ± 0.53 years) reported no significant correlation between FMS (measured using the TGMD) (Ulrich, 1985) and perceived physical competence ( $p>0.05$ ) (measured using Harter and Pike's (1984) Pictorial Scale of Perceived Competence and Social Acceptance). Furthermore, Spessato, Gabbard, Robinson, et al. (2013), among 4-7 year old Brazilian children (N=178, mean age: 5.4 ± 1.00 year), found no significant relationship between actual FMS competence (measured using the TGMD-2) and perceived competence (measured using the physical competence subscale of the Pictorial Scale of Perceived Competence and Social Acceptance) among 7, 8, or 9 year olds ( $p>0.05$ ), but reported a significant, albeit weak ( $r=.29, p<0.05$ ), correlation among 6 year olds.

To date, few published studies have examined the relationship between actual and perceived FMS competence using aligned tools. Barnett, Ridgers, and Salmon (2015), who measured perceived competence using the Pictorial Scale of Perceived Movement Skill Competence and FMS using the TGMD-2, reported a positive association between children's perceived and actual object-control competence among a cohort of 4-8 year old Australian children (N=102). The study found that for each increase in object-control skill score (object-control score range: 0-48), perceived object-control competence (range 6-24) would increase by 0.11 units. Children's actual and perceived locomotor skill competence levels were not reported in the study. Liong et al. (2015), among 5-8 year old Australians (N=136), also reported a significant relationship between children's actual and perceived OC competence using the same assessment tools. It should be

noted, however, that the correlation was weak in size and on analysis by sex, was only significant among boys ( $r=.26$ ,  $p<0.05$ ). Furthermore, no significant relationship was found between children's actual and perceived locomotor competence, or between their TGMD-2 total score and their total perceived competence score ( $p>0.05$ ). These findings of Liong et al. (2015), that revealed no significant relationship between overall FMS and perceived competence, support previous research that suggests that young children, due to their limited cognitive capacity, cannot accurately perceive their actual competence (Goodway & Rudisill, 1997; Harter, 1987; 1999; 2012; Harter & Pike, 1984; Stodden et al., 2008).

Stodden et al. (2008) suggest that the relationship between actual and perceived competence emerges as children age. However, a recent study by Barnett et al. (2018) also reported no significant relationship between children's actual and perceived locomotor or between actual and perceived object-control competence among older children (8-11 years of age,  $N=118$ ) ( $p>0.05$ ). While the authors acknowledged that the lack of significant findings may have been due to a lack of variability in perceived competence scores and higher actual competence scores compared to previous research), the results suggest that it may be only when children reach the formal operational intelligence stage of development (approximately 11-12 years) (Piaget, 1955) or even the adolescent years before children can accurately perceive their actual competence. Others have suggested that children evaluate their competence levels in terms of the product of movements, e.g. the distance jumped, whether the ball was retained in the hands or not (Barnett et al., 2018), as opposed to the process (or technique) which is what is often evaluated in the measurement of actual FMS competence. This may explain the insignificant relationship between actual and perceived FMS competence that is often reported in the research.

#### Levels of Perceived Competence

Research generally reports high levels of perceived competence among children (Bardid, De Meester, et al., 2016; De Meester et al., 2016; Khodaverdi et al., 2016). De Meester et al. (2016) who assessed the perceived competence of a cohort of USA children ( $N=361$ , mean age:  $9.5 \pm 1.24$  years) via the sport/athletic subscale of Self-Perception

Profile for Children (Harter, 2012) which has a maximum score of four, reported a mean perceived competence score of  $3.1 \pm 0.57$ . Bardid, De Meester, et al., (2016) who also used the sport/athletic subscale of Self-Perception Profile for Children (Harter, 2012) in their assessment of perceived competence, reported similarly high perceived competence scores (mean:  $3.2 \pm 0.57$ ) among 7-10 year old Belgian children (N=161). Liong et al. (2015) reported a relatively high level of perceived FMS competence among 5-8 year old Australian children (N=136), assessed via the Pictorial Scale of Perceived Movement Skill Competence, with a mean perceived FMS score of 40.5 (maximum possible score of 48). Relatively high perceived FMS competence levels were also reported among an older cohort of Australian children (mean age:  $9.9 \pm 0.7$  years) with mean scores of 19.8 (maximum possible score: 24) and 18.5 (of a possible 24) recorded for perceived OC proficiency and perceived LOCO proficiency respectively, using the Pictorial Scale of Perceived Movement Skill Competence (Barnett, Ridgers, Zask, et al., 2015). These high levels of perceived competence, very often the overestimation of actual competence among children, provide a 'window of opportunity' or highlight the childhood years as an opportune time for intervention during which children are likely to persist in an activity irrespective of actual levels of competence (LeGear et al., 2012; Stodden et al., 2008). It is critically important to develop actual FMS competence at this age so that when children develop cognitively and can accurately perceive their abilities, they will engage in the positive spiral of participation (resulting in increased levels of PA and more favourable levels of adiposity) proposed by Stodden et al. (2008).

Research examining sex-related differences in perceived competence has reported mixed findings. Some studies have reported higher perceived competence among boys than girls (Carroll & Loumidis, 2001; De Meester et al., 2016; Robinson, 2011). Some believe this is due to the greater amount of time boys spend engaged in PA (Carroll & Loumidis, 2001) while others suggest it is due to environmental factors such as the greater encouragement and support given to boys to participate in PA compared to girls (Telford, Telford, Olive, et al., 2016). In contrast, however, LeGear et al. (2012) found higher perceived competence among girls than boys. Furthermore, others have reported no difference in perceived competence levels between boys and girls (Goodway & Rudisill, 1997; Harter & Pike, 1984). It should be noted that these studies

by Carroll and Loumidis (2001), De Meester et al. (2016), Robinson (2011), Harter and Pike (1984), Goodway and Rudisill (1997) and LeGear et al. (2012) assessed children's perceptions of general movement/athletic competence (in tasks such as playing games and sports, running, hopping, swinging, climbing, tying shoelaces and skipping). Findings from research that have used the Pictorial Scale of Perceived Movement Skill Competence (Barnett, Ridgers, Zask, et al., 2015), which assesses the perceived competence of children in 12 FMS (6 locomotor (LOCO) and 6 object-control (OC)), have reported superior perceived competence levels among boys for OC skills (Barnett, Ridgers, & Salmon, 2015; Barnett et al., 2018; Liong et al., 2015; Slykerman et al., 2016) but no sex-related difference in perceived LOCO skill competence (Barnett et al., 2018; Liong et al., 2015; Slykerman et al., 2016).

Robinson (2011), among 119 American pre-school children (mean age  $4.0 \pm 0.55$  years), reported a significant small positive relationships between TGMD-2 total score and perceived competence among boys ( $r=.31, p<0.05$ ) and a significant moderate positive relationship between these two variables among girls ( $r=.51, p<0.05$ ). A small positive correlation between OC score and perceived competence ( $r=.35, p<0.05$ ) and a significant moderate relationship between LOCO and perceived competence ( $r=.51, p<0.05$ ) were observed among the girls while small correlations were observed for both relationships among boys (OC and perceived competence,  $r=.28, p<0.05$ ; LOCO and perceived competence,  $r=.29, p<0.05$ ). Similarly, LeGear et al. (2012) found a stronger correlation between FMS score and perceived competence among girls ( $r=.33, p<0.01$ ) than boys ( $r=.24, p<0.01$ ). This study also reported a stronger correlation between LOCO and perceived competence among girls ( $r=.37, p<0.01$ ) than boys ( $r=.22, p<0.01$ ). These findings suggest that the relationship between actual and perceived competence is stronger among girls, and thus girls may have a more accurate perception of their actual motor competence than boys. In contrast to these findings however, LeGear et al. (2012) found that the relationship between OC and perceived competence was significant among boys ( $r=.21, p<0.05$ ) but not among girls ( $p>0.05$ ).

## 2.5 School-Based Interventions

This section provides an overview of primary school-based PA-based interventions. The importance of intervention delivery among children, and in particular among Irish children is discussed. This section reviews evidence-based recommendations for school-based interventions and the effectiveness of (i) PA interventions on markers of health, (ii) FMS interventions on FMS proficiency and (iii) FMS interventions on FMS and markers of health. A number of Irish school-based interventions are also reviewed.

### Intervention during the Primary School Years

Low levels of FMS, PA and fitness and high levels of overweight and obesity have been reported among children, adolescents and adults. Given that FMS, PA and fitness track from childhood into later years (Telama et al., 2014; Twisk et al., 2000), the childhood years, when children are likely to persist with PA irrespective of their actual competence (because of their inflated perceived competence) appears to be an opportune time for intervention. Furthermore, the primary school years (4-13 years) have been identified by Gallahue and Ozmun (2006) as an optimal time for FMS development. Various PA-based interventions among children have been successful, with the adoption of healthier lifestyle behaviours and positive health outcomes reported as a result (Kriemler et al., 2011; Logan et al., 2011;; Morgan et al., 2013; Mura et al., 2015; Waters et al., 2011), further encouraging their implementation at this stage.

The primary school setting in particular has been identified as an opportune setting for intervention (Centers for Disease Control and Prevention, 2011; Dobbins, de Corby, Robeson, Husson, & Tirilis, 2009) due to the large number and diversity of children that attend (Story, Nanne, & Schwartz, 2009), the large amount of time children spend there (Kriemler et al., 2011; Rush et al., 2012) and the vast facilities that are often available (e.g. classrooms, halls, yards) (Mura et al., 2015). Irish primary school children spend most of their 5-6 hour (Irish National Teacher's Organisation, 2017) school day engaged in sedentary activities (e.g. reading, writing, listening to the teacher) and thus the school day has huge potential to become more physically active (Belton, O'Brien, Issartel, McGrane, & Powell, 2016; van Stralen et al., 2014). Further to this, physical education

(PE) provides children with the opportunity to not only engage in PA (Kobel, Kettner, Lammler, & Steinacker, 2017; McKenzie, & Lounsbery, 2009; Payne & Morrow, 2009; Scheerder et al., 2008; Ward, Saunders, & Pate, 2007), but also to learn skills that will allow them to be active outside of school and in later life (Green, 2008; Mitchell et al., 2013; van Beurden et al., 2003).

While primary schools have been highlighted as important settings for intervention, reviews that have examined the effectiveness of interventions aiming to improve PA and/or prevent/reduce overweight/obesity among children highlight that those that are successful tend to be multi-component in nature (Amini, Djazayeri, Majezadeh, Taghdisi, & Jazayeri, 2015; Dobbins et al., 2009; Kriemler et al., 2011; Salmon, Booth, Phongsavan, Murphy, & Timperio, 2007; Shirley et al., 2015) and should include both schools and families (Dobbins, Husson, DeCorby & LaRocca, 2013; Heitzler, Martin, Duke, & Huhman, 2006; Salmon et al., 2007; Waters et al., 2011). Dobbins et al. (2013), in a review of 26 studies, outlined that teachers and parents have key roles to play in school-based PA interventions to improve the PA and CRF of children. Furthermore, Salmon et al. (2007), in a review of 76 studies, reported that multi-component interventions that focused on PE and included PA breaks or family-based strategies were most effective. Similarly, Kriemler et al. (2011) outlined that multi-component school-based interventions that involved specialists as well as family support appeared to be effective for increasing PA among children.

PA and PE of sufficient quantity and quality is lacking in schools (Hardman, 2008; Woods et al., 2010). Barriers to providing adequate levels of PA/PE have been identified (Harris, Cale, & Musson, 2012; Morgan & Hansen, 2007; 2008) and include the delivery of PA/PE lessons/sessions/programmes by classroom teachers who often lack confidence and competence in the area (Hardman, 2008; Morgan & Hansen, 2008), an overcrowded curriculum/time constraints (Cothran, Kulinna, & Garn, 2010; Morgan & Hansen, 2008; Naylor et al., 2015) and intense pressure on teachers to raise the academic performance of students (Wechsler et al., 2004).

### Interventions in Irish Primary Schools

Low FMS proficiency (Bolger et al., 2017; Farmer et al., 2017), PA (Woods et al., 2010) and fitness (Hudson et al., 2015; Woods et al., 2010) have been reported among Irish primary school children, highlighting the need for intervention among this cohort. A study among a sample of Irish primary school children (N=98, mean age: 11.2 ± 1.2 years) by Hegarty, Murtagh and Ní Chróinín (2016) demonstrated the lack of PA that children accumulate during the school day. It was reported that boys engaged in just over 20 minutes of MVPA during the school day, while girls engaged in less than 15 minutes MVPA per school day, highlighting the potential for improvement during the school period. While children have the potential to master FMS by the age of 6 years, findings by O'Brien et al. (2016a) reported that only 11% of Irish adolescents demonstrated mastery/near mastery in all 9 FMS tested, emphasising the need for intervention during the primary school years.

The quantity or amount of time recommended for PE among primary school children in Ireland is the lowest of all the EU countries (European Commission/EACEA/Eurydice, 2013). Primary school PE is a legal requirement in 89% of countries worldwide (Hardman, 2008). However, Ireland is not one of these countries. In Ireland, the delivery of PE is merely a recommendation. The Department of Education and Skills recommend that Irish primary school children engage in 60 minutes of PE per week while their counterparts in the UK engage in 120 minutes of mandatory PE per week (Bardens, Long, & Gillie, 2012). Children in France engage in over three times the amount of PE that Irish children do (108 hours vs 37 hours per year) (European Commission/EACEA/Eurydice, 2013). Worryingly, despite this shorter recommended time among Irish children, Woods et al. (2010) have reported that only 35% of Irish primary schools actually engage in this one hour of PE per week. The average time spent in PE per week was 46 minutes. These findings are consistent with those of Halbert and MacPhail (2005) who found that the average time spent in PE in Ireland ranged from 12-60 minutes and that three-quarters of students had less than 30 minutes of PE each week. Furthermore, despite recommendations that students should be engaged in MVPA for at least 50% of PE class (Fairclough & Stratton, 2005; US Department of Health and Human Services, 2000) research has found that primary school children typically spend much less than this

engaged in MVPA during PE (Fairclough & Stratton, 2005; Nader & National Institute of Child Health and Human Development Study of Early Child Care and Youth Development Network, 2003; van Beurden et al., 2003; Waring, Warburton, & Coy, 2007; Wood & Hall, 2015). While no research has investigated the proportion of time that Irish primary school children spend in MVPA during PE class, Wood and Hall (2015) who collected PA data via accelerometers from a cohort of 20 English children (mean age:  $9.4 \pm 0.5$  years) found that a mere 9.5% of PE time was spent engaged in MVPA. Furthermore, a study by Waring et al. (2007) that involved direct observation of children during PE class, it was reported that 5-11 year old children from the North-east of England (N=374) spend 18% of PE time in MVPA. While differences in findings may have been due to the difference in sample sizes, age ranges and/or PA measures (accelerometers versus direct observation), both studies highlight that primary school children do not spend 50% of PE time engaged in MVPA. Given the associated benefits of being competent in FMS (Lubans et al., 2010) and the potential for improvement in the provision of PE/PA in Irish primary schools, PA and/or FMS interventions have the potential to positively affect health and well-being of Irish primary school children.

#### Recommendations for School-Based Interventions

It is recommended that school-based PE/PA interventions should be developed based on theoretical models of behaviour change as such interventions have been found to be more successful than those that are not (Michie & Abraham, 2004). The socio-ecological model (SEM) (McLeroy, Bibeau, Steckler, & Glanz, 1988) is one such model. In contrast to models of behaviour change that have been criticised for their emphasis on the processes of individual behaviour change with little regard for the effect of socio-cultural and environmental conditions on behaviour (McLeroy et al., 1988), the SEM of behaviour change acknowledges that there are several levels of influence on behaviour (Bauman & Bull, 2007; McLaren & Hawe, 2005; Stokols, 1996). These influences are intrapersonal factors, interpersonal factors, institutional factors, community factors and public policy. The comprehensive approach offered by the SEM allows opportunities for PA and healthy behaviours to be identified by acknowledging the individual (e.g. skill level, perceived competence, beliefs and attitudes, knowledge), interpersonal/social environmental (family, teachers, peers) and physical environmental (e.g. availability of



PA equipment, facilities, healthy food options) factors that can impact on an individual's ability to be physically active (McLeroy et al., 1988; Richard, Potvin, Kishchuk, Prlic, & Green, 1996). Interventions that employ strategies that simultaneously affect these multiple levels may result in greater and longer lasting health behaviour changes (Stokols, 1992; US Department of Health and Human Services, 1996).

The Supporting Children's Outcomes using Rewards, Exercise, and Skills intervention (SCORES) is an example of an intervention that used the SEM. The SCORES was a 12-month primary school-based intervention that aimed to improve the PA and FMS levels of children from low-income communities (Cohen, Morgan, Plotnikoff, Callister, et al., 2015). The intervention was multi-component and simultaneously targeted multiple levels of factors identified in the SEM through:

- student leadership workshops
- the provision of opportunities to engage in PA promotion tasks (e.g. writing an article in the school newsletter) for students
- teacher development
- parent evenings
- FMS homework
- provision of PA-related equipment to the school
- the implementation of PA policies
- the establishment of a PA committee
- creating links between the school and community-based PA providers

The significant intervention effects for PA, FMS and CRF reported in this study post-intervention provide support for the use of the SEM in primary school-based PA and FMS based interventions.

Research suggests that components for effective interventions should include an increased provision for PA and FMS development (Dudley, Okely, Pearson, & Cotton, 2011) throughout the school week, classroom activity breaks (Murtagh, Mulvihill, & Markey, 2013; Naylor & McKay, 2009), the integration of PA into classroom lessons

(Kohl, Moore, & Sutton, 2001), the inclusion of home-based activities that encourage PA (Waters et al., 2011; Wechsler et al., 2004) and support for school staff (e.g. professional development) (Dudley et al., 2011; Lonsdale et al., 2012; Morgan et al., 2013; Waters et al., 2011; Wechsler et al., 2004). A recent review by Tompsett et al. (2017) found that FMS interventions are most effective for favourable physiological, psychological and behavioural health outcomes when delivered by a specialist and also include home-based activities. Multi-component interventions delivered by specialists and supported by parents are effective for increasing PA (Kriemler et al., 2011) and reducing obesity among children (Connelly, Duaso, & Butler, 2007). While it has been recommended that both teachers and researchers are involved in the implementation of interventions, the inclusion of parents is important as it allows information and knowledge to be transferred from school to the home setting (Riethmuller, Jones, & Okely, 2009).

The CDC's guidelines for interventions to promote lifelong PA and health highlight that PE should be of a high-quality (i.e. involve the teaching of FMS and ensure children engage in MPVA for 50% of PE time) and be delivered across 150 minutes every week (Wechsler et al., 2004). It has been suggested that longer interventions are more effective for the alteration of lifestyle behaviours than shorter interventions (Back Giuliano Ide et al., 2005; Dobbins et al., 2009; Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents, National Heart, Lung, and Blood Institute, 2011; Kavey et al., 2006; C. L. Williams et al., 2002). To support this, a systematic review by Lai et al. (2014) found that 80% of the 10 intervention studies that reported a sustained PA impact involved interventions of longer than 1 year.

With children spending a large proportion of their waking hours in school, Project Energize (New Zealand) suggest that children should engage in at least 20 minutes of MVPA during the school day (Rush et al., 2012) while others have recommended that children should spend at least 30 minutes of their school day engaged in MVPA (Nettlefold et al., 2011; Pate et al., 2006). As it has been found that children spend more time in MVPA on PE days than non-PE days (Kobel et al., 2017), it is not surprising that other researchers suggest that daily PE classes may be effective for optimising health in

childhood (Kemper, 2000; Marshall & Bouffard, 1997) and positively affecting long-term PA habits (Trudeau, Laurencelle, Tremblay, Rajic, & Shephard, 1999).

While a systematic outcome evaluation of an intervention assesses the effectiveness of an interventions on measured variables, process evaluation has been highlighted as an 'essential' part of evaluating complex interventions and thus should also be included in the overall evaluation of an intervention (Moore et al., 2015). Process evaluation is an investigation which aims to help researchers understand the functioning of an intervention. It often involves the examination of (i) implementation (ii) mechanisms of impact and (iii) contextual factors (Moore et al., 2015).

Implementation refers to what is delivered during an intervention and how it is delivered. Key elements of implementation include the implementation processes (the structures, resources and mechanisms through which the intervention was delivered), fidelity (whether the intervention was delivered as planned), adaptations (changes made to the intervention to improve its quality), dose (the quantity of the intervention received) and reach (whether the intervention comes in contact with the target audience or not, an if so, how).

Mechanisms of impact refer to the mechanisms through which intervention outcomes are achieved. The examination of the mechanisms of impact of an intervention may include capturing participants' responses to the intervention, identifying mediators of the intervention (i.e. processes or outcomes that explain subsequent outcomes), and identifying unintended and/or unexpected intermediate processes and outcomes. Contextual factors refer to factors external to the intervention that may affect the intervention's implementation, and/or its mechanisms of impact.

Process evaluation is very important for interventions as it can provide feedback relating to the feasibility of an intervention, help identify key components of the intervention, inform future interventions and provide feedback to allow for on-going improvement (Humphrey et al., n.d.; Moore et al., 2015). It also supports conclusions relating to the effectiveness of interventions by examining the quality and quantity of the delivered intervention, and also by examining the degree to which its effectiveness

is generalisable (Moore et al., 2015). For example, an intervention deemed to be 'ineffective' may have produced limited effects due to poor design or poor implementation (Steckler & Linnan, 2002). Alternatively, an intervention may result in desired outcomes despite not being delivered as planned or intended (Moore, Raisanen, Moore, Din, & Murphy, 2013). Outcome evaluation alone in these cases may lead to inaccurate conclusions. However, process evaluation through its examination of the intervention's implementation, mechanisms of impact and contextual factors will enable more accurate conclusions to be drawn.

Essentially, process evaluation strengthens the ability to report on an intervention and also provides information to improve the on-going intervention and/or future interventions as it determines the degree to which an intervention is implemented as intended and also identifies barriers and facilitators of the intervention (Centers for Disease Control and Prevention, 2012).

#### PA Interventions and Health

Reviews relating to the effectiveness of school-based PA interventions to improve various markers of health have produced mixed findings. A systematic review and meta-analysis of 20 randomised controlled trials that examined the effectiveness of school-based PA interventions on 3-12 year old children's CRF levels, found that interventions that included aerobic-based activities were effective with significant small increases in CRF (Hedges'  $g=0.22$ ,  $p<0.01$ ) (Pozuelo-Carrascosa, Garcia-Hermoso, Álvarez-Bueno, Fánchez-López, & Martinez-Vizviano, 2017). However, the increase in CRF was only significant among girls (Boys: Hedges  $g=0.02$ ,  $p>0.05$ , Girls: Hedges  $g=0.25$ ,  $p<0.01$ ), Dobbins et al. (2009), in a review of prospective, randomised controlled trials (RCTs) and controlled clinical trials that evaluated the effectiveness of school-based interventions on PA and fitness among 6-18 year olds, reported positive results for increased MVPA,  $VO_2\max$  (CRF), and reduced TV viewing time. However, the effectiveness of the reviewed studies on children's overall PA levels and BMI was limited. Mura et al. (2015), who reviewed 47 RCTs to evaluate the effectiveness of European school-based PA interventions (carried out between 2000 and early 2014), reported that the evidence was inconclusive in relation to changes in health outcomes including body composition (most commonly assessed by BMI), PA and fitness. A systematic review by Metcalf et al.

(2012) found that the positive effects of school-based interventions on objectively measured PA levels is at most small in size and only likely to have a minimal impact on health outcomes such as body composition or BP (Ekelund et al., 2012). In contrast, a review by Mei et al. (2016) that evaluated the effect of PA interventions among primary school children reported a significantly smaller increase in BMI among intervention groups compared to controls ( $p < 0.05$ ).

However, in a review of four comprehensive systematic reviews (published after 2006) that evaluated the effectiveness of school-based interventions among children and/or adolescents, Kriemler et al. (2011) concluded that interventions among children and adolescents do positively impact children's PA. Furthermore, a systematic review of health promoting interventions among children and adolescents published between 2007 and 2011 (that included a total of 20 studies, the majority of which were European based), reported that 100% of studies evaluating PA found that the intervention had a significant positive effect on at least one domain of PA (e.g. in-school PA, total PA) (Kriemler et al., 2011). Less conclusive evidence was reported for fitness and motor skills with 55% of those that evaluated fitness and 67% of those that evaluated motor skills reporting significant interventions effects. Interesting to note from the review by Kriemler et al. (2011) was that while FMS are positively associated with health benefits (Lubans et al., 2010), those studies reporting positive intervention effects on motor skills did not always find simultaneous positive effects on fitness/PA (Kriemler et al., 2011).

The success of an intervention is often evaluated based on the effect size of significant differences between pre- and post-intervention scores. However, Ory, Jordan, and Bazzarre (2002) define successful interventions as those that produce not only significant but also sustainable outcomes. A review by Lai et al. (2014) evaluated the sustained effect of child and adolescent based interventions on FMS, PA and fitness and found that 77% of the studies reported a sustained effect on PA in at least one measured PA variable. A sustained effect was found in overall PA (average minutes per day) (Taymoori et al., 2008), MVPA (minutes per week) (Manios & Kafatos, 2006; Manios, Kafatos & Kafatos, 2006) percentage of participants meeting recommended PA guidelines (Manios, Kafatos & Kafatos, 2006), moderate PA (minutes per day) (Salmon

et al., 2008), frequency of vigorous PA during a week (Klepp et al., 1994; Trudeau, Laurencelle, Tremblay, Rajic, & Shephard, 1998; Trudeau et al., 1999), vigorous PA (minutes per day) (Nader et al., 1999; Salmon et al., 2008), number of days per week in which children participated in leisure time PA (Bronikowski & Bronikowski, 2011), out of class exercise hours per week (Kelder, Perry & Klepp, 1993) and total step counts per day (Salmon et al., 2008). However, it should be noted that the majority of these studies used self-report methods of measurement, with only one using objective measures. Mean differences of up to 14 minutes per day were reported between intervention and control groups and it was concluded that PA is a sustainable outcome from interventions among children and adolescents. Less evidence is available to determine the sustainability of fitness (three studies met the inclusion criteria) and FMS (two studies met the inclusion criteria) following interventions among children and adolescents. However, it would appear that FMS may also be a sustainable outcome with both of the studies that assessed FMS (Barnett, van Beurden, Morgan, Brooks, & Zask, et al., 2009; Salmon et al., 2008) demonstrating a sustained effect, with one showing sustained effects for both FMS and PA (Salmon et al., 2008). In contrast, only one of three of the studies that evaluated fitness reported a sustained impact.

A PA intervention by Kriemler et al. (2010) carried out among 1<sup>st</sup> and 5<sup>th</sup> grade Swiss students (N=498, mean age: 6.9 ± 0.3 years and 11.1 ± 0.5 years for 1<sup>st</sup> and 5<sup>th</sup> grade students, respectively) across one academic year (9 months) reported positive intervention effects. The MVPA levels of the intervention group (who had five 45-minute PE lessons per week, three taught by the classroom teacher and two by a PE teacher, 3-5 short daily activity breaks and homework) improved significantly more than the control group (who had their usual three mandatory 45-minute PE lessons per week taught by the classroom teacher) with the intervention group engaging in 11 minutes more MVPA per day post-intervention ( $p < 0.05$ ). The intervention group also improved significantly more than the controls ( $p < 0.05$ ) in CRF (measured using the 20m SRT) (Léger, Mercier, Gadoury, & Lambert, 1988), in-school PA and cardiovascular risk score. Furthermore, significantly smaller increases in the sum of four skinfolds were observed among the intervention group when compared to their counterparts in the control group ( $p < 0.01$ ), suggesting that the intervention also had a positive effect on children's

body composition. However, no significant intervention effects were reported for WC or BP ( $p>0.05$ ).

The effectiveness of Project Energize, the primary school-based PA and health eating intervention that is delivered across the Waikato region of New Zealand, also revealed positive intervention effects for a number of markers of health; adiposity, BP (Rush et al., 2012) and CRF (Rush et al., 2014). The initial evaluation of the project, a longitudinal RCT, was carried out over a two year period (2004-2006) and involved 62 intervention and 62 control schools. Children (N=1,352) were aged 5 and 10 years at baseline and 7 and 12 years at follow-up. Results of the study revealed favourable effects for the intervention with slower gains in body fat percentage SDS observed among the 5-7 year old intervention group compared to their counterparts in the control group (0.64 v 0.79,  $p<0.05$ ) (Rush et al., 2012). A decrease in SBP SDS was also found among the 10-12 year old intervention group while an increase was observed among the control (-0.18 vs. 0.05,  $p<0.05$ ) (Rush et al., 2012). Furthermore, it was noted that 90% of schools had reported enhanced knowledge of healthy eating and PA at follow-up (Rush et al., 2012). A further evaluation of Project Energize, involved 7- and 10-year old children from 193 intervention schools (N=4,804). The study found that the prevalence of overweight and obesity in 2011 among 7 and 10 year old 'Energized' children (i.e. those who had received the intervention) was 15 and 31% lower, respectively, than that reported among 'unEnergized' children measured in 2004 (Rush et al., 2014). The Energized children also demonstrated higher (approximately 10%) CRF levels (measured as time taken to complete 550m) when compared to children of a similar age from Canterbury New Zealand (Rush et al., 2014), suggesting that the intervention is effective for the improvement of primary school children's health and well-being.

#### FMS Interventions and FMS Levels

FMS are the building blocks of movement that allow for participation in sport and PA. The development of FMS requires quality instruction, feedback and practice (Gallahue et al., 2012; Logan et al., 2011). Many interventions have aimed to improve FMS proficiency among children. Some FMS-based intervention evaluations have focused solely on FMS outcomes (e.g. increases/decreases in overall proficiency scores, mastery

levels of skills) while others have also considered their effectiveness on physiological, psychological and behavioural outcomes.

Logan et al. (2011), in a meta-analysis of the effectiveness of motor skill interventions among children, reported that FMS interventions were effective at improving children's FMS proficiency ( $p < 0.01$ ; as measured using process-oriented assessment tools), with similar improvements reported among LOCO and OC skill subsets. However, it should be noted that 7 of the 11 reviewed studies were carried out among children who were developmentally delayed or at risk of delay in the motor domain and so there may have been greater potential for improvement among these children.

A systematic review and meta-analysis conducted by Morgan et al. (2013) among typically developing children and adolescents consolidated the findings of Logan et al. (2011) as they found that every study in the review reported significant improvements in at least one FMS measure ( $p < 0.05$ ). The meta-analysis reported significant intervention effects for overall FMS proficiency (standardised mean difference=1.42,  $p < 0.01$ , large effect size) as well as LOCO (standardised mean difference=1.42,  $p < 0.01$ , large effect size) and OC competence (standardised mean difference=0.63,  $p < 0.01$ , moderate effect size). Two studies reported significant long-term effects on FMS at 6 and 9 year follow-ups ( $p < 0.05$ ) (Barnett, van Beurden, Morgan, Brooks, Zask, et al., 2009; Ericsson, 2011). In contrast to Logan et al. (2011), the review and meta-analysis by Morgan et al. (2013) included interventions that evaluated FMS proficiency using both process- and product-oriented assessments and involved both children and adolescents. However, the majority of interventions (95%) were implemented among primary school aged children. While previously evaluated interventions may differ greatly in terms of content, structure, duration, delivery and pedagogical approach amongst others, it appears that FMS interventions are effective for the development of FMS proficiency among children.

A Project Energize intervention that involved the support and mentorship of teachers for the delivery of an FMS intervention to 5-12 year olds ( $N=701$  for locomotor skills,  $n=598$  for object-control skills) from New Zealand, produced significant improvements



in all 12 FMS tested ( $p < 0.01$ ) (Mitchell et al., 2013). Improvements in the prevalence of skill mastery, i.e. the proportion of children that demonstrated correct skill technique, measured using the TGMD (Ulrich., 1985) ranged from 13.7% in the run to 36.3% in the strike. Increases in mastery prevalence of over 25% were found in 9/12 skills assessed. While the study design did not include a control group, the study adds to the body of literature supporting the implementation of FMS based interventions among primary school aged children.

#### FMS Interventions and Other Outcomes (in addition to FMS)

A review by Tompsett et al. (2017) of 29 interventions targeting FMS and at least one physiological, psychological or behavioural outcome among children and adolescents reported significant increases in FMS proficiency among all but two studies. While only 11 studies evaluated CRF as an outcome, 9 of these studies reported significant improvements following an FMS intervention. Of the 12 studies that evaluated body composition (BMI, BMI z-score, WC, body fat percentage), only five found significant improvements, with the improvement in three of these studies likely to be attributable to nutritional components of multi-dimensional interventions (Tompsett et al., 2017). Thus, although FMS has been found to be inversely associated with adiposity level (Lubans et al., 2010), the effectiveness of FMS-based interventions to reduce overweight and obesity is questionable. It has been suggested that FMS-based interventions may not have a significant effect on adiposity level in the short-term but improved FMS proficiency may play a role in the prevention/reduction of overweight/obesity in the long-term (Cliff et al., 2012). However, further research is warranted to assess such outcomes in longitudinal studies. Three of the four studies evaluating perceived athletic competence in the review by Tompsett et al. (2017) found positive intervention effects, while some also found positive effects for impulse control and inhibition, global self-concept, attention, and PA enjoyment. A total of 64% of the studies evaluating PA reported significant positive intervention effects. Those interventions that reported increases in PA also reported improvements in FMS. However, it could not be inferred as to whether increases in PA resulted in concurrent improvements in FMS or vice versa. Overall, the review provided substantial evidence supporting the implementation of FMS-based intervention to improve FMS proficiency, CRF, perceived competence and

PA and concluded that the most effective interventions are specialist-led FMS and PA school-based interventions which also include a home-based component which allows for parental involvement (Tompsett et al., 2017).

The 'Move It Groove It' intervention (which included a teacher support or 'buddy' system, teacher professional development, the establishment of a programme website and financial support for resources) that was evaluated among 7-10 year old Australian children (N=1,045) resulted in significantly greater improvements in FMS among intervention group when compared to the control ( $p<0.01$ ) (van Beurden et al., 2003). A total of 8 FMS were tested in the study and improvements in the mastery/near mastery levels of the skills ranged from 7% (the throw among girls) to 26% (the sprint run among boys) (van Beurden et al., 2003). However, no significant difference was found between pre- and post-intervention PE class MVPA ( $p>0.05$ ). It should be noted that PA was measured by direct observation using a tool called the System for Observing Fitness Instruction Time (SOFIT) (McKenzie et al., 1994; McKenzie, Sallis, & Nader, 1991) and only among a subsample of participants. Observations of the content of PE found that there was an increase in the time spent on FMS instruction and a decrease in time spent on fitness and games, highlighting that the proportion of time necessary for the development of FMS may limit the amount of time available for engagement in MVPA during PE lessons (van Beurden et al., 2003). Acknowledging the challenge for interventions to improve both FMS and PA, the authors suggested an extra 20 minute daily fitness/PE lesson may be necessary to improve weekly PA levels (due to the demand on time for FMS development during PE lessons).

The Supporting Children's Outcomes using Rewards, Exercise and Skill (SCORES) 12-month primary school-based multi-component intervention that aimed to improve the FMS proficiency, CRF and PA levels of Australian children from low-income communities reported no significant group-time interaction after 6 months for any FMS, CRF or PA variables ( $p>0.05$ ) (Cohen, Morgan, Plotnikoff, Callister, et al., 2015). However, at 12 months, relative to the control group, there were significant positive effects reported among the intervention group for overall FMS (4.9 units,  $p<0.05$ ), CRF (equating to an additional 5 laps on the 20m SRT,  $p<0.01$ ), daily MVPA (corresponding to 13 additional

minutes MVPA per day,  $p<0.01$ ), daily after-school MVPA (4.6 minutes MVPA per day,  $p<0.05$ ) and weekend MVPA (14.5 minutes per day,  $p<0.05$ ). These findings support suggestions that interventions of longer duration are more effective than shorter interventions (Dobbins et al., 2009) and also that FMS-based interventions can significantly improve CRF and PA simultaneously to FMS.

The 5-month FMS- and PA-based Go2Play Active Play intervention delivered to 189 Scottish children, which was facilitated by play workers and consisted of 1 hour weekly sessions (30 minutes of structured FMS games and 30 minutes of free play) reported significant intervention effects for gross motor quotient (GMQ) score and GMQ percentile ( $p<0.05$ ) (Johnstone, Hughes, Janssen, & Reilly, 2017). On analysis of the FMS subsets, there were significant intervention effects for LOCO score ( $p<0.05$ ) and LOCO percentile ( $p<0.05$ ), with no significant intervention effect observed for OC score ( $p>0.05$ ) nor OC percentile ( $p>0.05$ ). There were significant intervention effects for PA, percent time in sedentary behaviour, light PA and MVPA (with PA variables measured across the school day only) ( $p<0.01$ ). The intervention group demonstrated a significant 258 counts per minute increase in total PA, a 15.7% and 2.8% increase in time spent in light PA and MVPA respectively, and a significant decrease of 18.6% in time spent in sedentary behaviour (all  $p<0.01$ ).

Bryant, Duncan, Birch, and James (2016), among children from two primary schools in England (N=165, mean age:  $8.3 \pm 0.4$  years), found that a 6 week school-based intervention that focused on one of two weekly PE lessons on FMS, produced significantly greater improvements in 7/8 FMS among the boys and girls in the intervention group compared to their counterparts in the control group ( $p<0.01$ ). There was no significant difference in BMI in the intervention or control group ( $p>0.05$ ). A significant intervention effect was found for objectively measured PA (mean daily steps) among girls ( $p<0.01$ ). While significant increases in perceived competence were found among the intervention and control groups ( $p<0.05$ ), no significant group by time interaction was observed ( $p>0.05$ ).

FMS interventions among primary school children appear to be effective at improving FMS proficiency as well as markers of health such as PA and CRF. The effect of FMS interventions on other markers of health such as body composition and perceived competence remains unclear and warrants further investigation. Furthermore, the effectiveness of FMS interventions on BP has yet to be investigated.

#### Irish School-Based PA /FMS Interventions

There is a limited amount of data relating to the effectiveness of school-based PA/FMS interventions among Irish youth (Martin & Murtagh, 2015; Murtagh et al., 2013; O'Brien, Issartel, & Belton, 2013). The 'Bizzy Break!' intervention was a school-based intervention carried out among 2<sup>nd</sup>-6<sup>th</sup> class children from four rural Irish schools (Murtagh et al., 2013). This intervention consisted of daily classroom PA breaks (of mobility, stretching and high intensity exercises with music) and was conducted over five school days. Despite there being a significant group-time interaction in favour of the intervention group ( $p < 0.05$ ), declines in objectively measured in-school PA (mean daily steps) were reported both intervention and control groups.

An intervention conducted by Martin and Murtagh (2015), that integrated PA into two classroom lessons (one maths and one English) daily, found that children engaged in 18 minutes light PA and 8 minutes MVPA during the two active lessons compared to the control who engaged in 0.3 minutes of MVPA during regular lessons. The intervention appeared to be equally effective for boys and girls with similar amounts of MVPA accumulated during the active lessons by both sexes (Girls: 8.3 minutes vs Boys: 7.5). Despite children who participated in the 'Active Classroom' intervention accumulating almost twice as much MVPA during the whole school day (15 minutes) than previously reported for school-day MVPA among Irish children (8 minutes) (Murtagh et al., 2013), it should be noted that the intervention was carried out by one teacher over a very limited time frame (5 days) and so the sustainability of the project over a longer period is questionable with a large amount of teacher input (in order to integrate PA into their lessons) required.

The Youth Physical Activity Towards Health (Y-PATH) intervention was a 9 month multi-component PA/FMS intervention carried out among Irish adolescents that involved PE classes delivered by specialist PE teachers, the distribution of information to parents (via an information evening and leaflets), two professional development workshops for participating teachers and the establishment of a project website. The evaluation of the project was carried out at the end of the intervention (9 months) and 3 months later (at 12 months) among 12-14 year olds (N=102) (O'Brien et al., 2013). The study revealed no significant intervention effects on BMI ( $p>0.05$ ). However, significantly larger improvements in PA ( $p<0.01$ ) and FMS proficiency ( $p>0.05$ ) were found among the intervention than the control. At retention (12 months), the intervention group engaged in 7.2 minutes more MVPA than the control, suggesting that PA/FMS interventions may effectively increase PA participation and FMS proficiency among Irish youth. However, it should be noted that this intervention was carried out among an adolescent cohort. Given the low levels of FMS (Bolger et al., 2017; Farmer et al., 2017) and markers of health among Irish children, and the dearth of rigorously developed and evaluated interventions, there is a need to design, develop, implement, and evaluate such an intervention among Irish primary school children.

This literature review has provided an overview of FMS, a number of markers of health (overweight/obesity, CRF and PA), perceived competence and school-based PA interventions. In conclusion, FMS are important basic movement skills that allow for participation in sport and PA. FMS proficiency is positively associated with a number of markers of health among children including PA, perceived competence, and health-related fitness and negatively associated with adiposity level (Robinson et al., 2015). School-based FMS interventions have been shown to be effective at improving FMS proficiency among children (with some interventions also reporting improvements in markers of health). Given the low FMS, PA and CRF levels of Irish children and reports that predict Ireland's rise to become the fattest nations in the EU, school-based PA and/or FMS interventions may have the potential to improve these measures.

# **Chapter 3:**

## **Methods**

### 3.1 Introduction

This research evaluated the baseline FMS proficiency and markers of health (overweight/obesity, CRF, PA) of a cohort of Irish primary school children. It evaluated the effectiveness of two school-based interventions on children's FMS proficiency and markers of health. The interventions delivered as part of this research were carried out during separate academic years. A PA intervention was delivered during the academic year 2014/2015 while an FMS-based intervention was delivered during academic year 2015/2016.

This research was conducted as part of larger research study, *Project Spraoi*, a primary school-based PA and nutrition intervention project. Project Spraoi is based on Project Energize, a community-based through-school PA and nutrition programme delivered to schools in the Waikato region of New Zealand. Both projects (Spraoi and Energize) are delivered to schools by trained individuals called 'Energizers'. Energizers are teachers and/or sport science, exercise, nutrition or physical education graduates. Project Spraoi 'Energizers' are also postgraduate researchers in the area of children's PA and/or nutrition. Energizers deliver the project to schools by acting as agents of change in the respective schools (rather than being an additional staff member in the school). Energizers work by supporting school staff members to promote PA and healthy eating among the students. Energizers do this in numerous different ways including modelling PA sessions (e.g. sessions that allow for maximum participation of all students, FMS lessons, huff and puff lessons, gymnastics lessons), setting up whole-school PA initiatives, providing PA resources (e.g. equipment, games manuals), forming links between the school and PA providers in the local community (e.g. with local sports clubs, universities for the use of facilities), establishing PA committees, aiding in the development of PA and healthy eating policies, providing healthy eating promotional material (e.g. fridge magnets), organising healthy eating parent information evenings or simply being available to talk to or answer any questions teachers may have in relation to PA and nutrition.

Two intervention and one control school were selected to participate in the current research. Both interventions were delivered to all children in the two schools selected for the intervention process. The schools selected to participate in the current research were chosen as they were the next on the list of applicant schools who met the inclusion criteria of Project Spraoi. For schools to be considered for Project Spraoi, it was required that the schools were (i) in close proximity (within approximately 20 km) to Cork Institute of Technology, (ii) willing to implement the Project Spraoi intervention, and (iii) not participating in any other PA and/or healthy eating intervention (Coppinger et al., 2016). As it was neither practical nor feasible to evaluate the project using the entire school populations, a subsample was selected for evaluation. As the evaluation of Project Energize was carried out among 5 and 10 year old children (Rush et al., 2012), senior infants and 4<sup>th</sup> class children (i.e. children aged approximately 5-6 and 9-10 years old) were selected for the evaluation of the first intervention (the PA intervention) that was delivered as part of this research. In an attempt to use a larger sample size for the evaluation of the second intervention (the FMS-based intervention), senior infant (5-6 years), 1<sup>st</sup> (6-7 years), 4<sup>th</sup> (9-10 years) and 5<sup>th</sup> (10-11 years) class children were invited to participate in the FMS-based intervention i.e. two additional class groups (the 1<sup>st</sup> and 5<sup>th</sup> classes) were added to the sample from which data were collected.

Ethical approval was sought and granted from Cork Institute of Technology Research Ethics Review Board in September 2014.

### **3.2 Participants**

In September 2014, 308 children from the senior infant and 4<sup>th</sup> classes from two intervention (one urban single-sex boys; one urban single-sex girls) and one control (rural mixed) school were invited to participate in the study, i.e. the evaluation of a PA intervention. A total of 217 children provided written assent and written parental consent (70.5% consent rate) which were required for participation in the study. Demographic information relating to these children is presented in Table 3.1.



In September 2015, children from the 1<sup>st</sup> and 5<sup>th</sup> classes (i.e. those in the senior infant and 4<sup>th</sup> classes the previous academic year) of the same two intervention schools and the same control school were invited to participate in the evaluation of an FMS-based intervention. The new senior infant and 4<sup>th</sup> class children in each of the schools were also invited to participate. Of the 605 children invited to participate in the evaluation (i.e. senior infant, 1<sup>st</sup>, 4<sup>th</sup> and 5<sup>th</sup> class children), a total of 466 provided written assent and parental consent to participate (77 % consent rate). Demographic information relating to these children is presented in Table 3.2.

It should be noted that while only a small number of class groups participated in the evaluation of the interventions, all children (from junior infants to 6<sup>th</sup> class) in the intervention schools received both the PA and FMS-based interventions i.e. children who participated in the evaluation of the FMS intervention had previously received a PA intervention. This may have influenced the uptake of the FMS intervention and thus should be noted as a limitation of the evaluation of the FMS intervention.

**Table 3.1:** Demographic information of children who provided data pre-and-post PA intervention (2014/2015)

	Senior Infants (n=107)			4 <sup>th</sup> Class (n=110)		
	Boys (n)	Girls (n)	Age (Mean ± SD)	Boys (n)	Girls (n)	Age (Mean ± SD)
Intervention (n=111)	30	24	5.87 ± 0.42	29	28	9.87 ± 0.43
Control (n=106)	26	27	6.13 ± 0.34	31	22	9.95 ± 0.36

**Table 3.2:** Demographic information of children who provided data pre-and-post FMS intervention (2015/2016)

	Senior Infants/1 <sup>st</sup> Class (n=222)			4 <sup>th</sup> /5 <sup>th</sup> Class (n=244)		
	Boys (n)	Girls (n)	Age (Mean ± SD)	Boys (n)	Girls (n)	Age (Mean ± SD)
Intervention (n=266)	67	60	6.32 ± 0.61	72	67	10.39 ± 0.63
Control (n=200)	47	48	6.61 ± 0.59	62	43	10.51 ± 0.53

### **3.3 Measures Collected**

Data were collected by the principal researcher in conjunction with other members of the Project Spraoi Research Team. Those involved in the data collection process are subsequently referred to as 'evaluators'. Data were collected at four time points; October 2014 (pre-PA intervention), May-June 2015 (post- PA intervention), September-October 2015 (pre-FMS intervention) and May-June 2016 (post-FMS intervention).

Measurements recorded at pre- and post-PA intervention (2014/2015) were FMS proficiency (using the TGMD-2), height, mass, WC, BP, heart rate, 550m run/walk time and objectively measured PA (via accelerometry). All measures used in the evaluation of the PA intervention were also collected pre- and post-FMS intervention (2015/2016). Although WC was measured (pre- and post-FMS intervention), there were errors made during data collection (with inconsistencies in the protocols used at pre- and post-intervention) and thus the data was not valid for use in the evaluation of the intervention and are not reported. Perceived FMS competence was added to the battery of measures collected pre- and post-FMS intervention. (This measure was not collected pre- or post-PA intervention).

#### **3.3.1 FMS**

The Test of Gross Motor Development-2 (TGMD-2) (Ulrich, 2000) was used to measure FMS proficiency in the sample population/cohort. The TGMD-2 is a valid and reliable process-oriented FMS assessment tool appropriate for 3-10 year olds (Ulrich, 2000). The test consists of 12 skills; 6 locomotor (run, leap, hop, gallop, slide and horizontal jump) and 6 object-control (two-handed catch, overarm throw, underhand roll, kick, two-handed strike and stationary dribble) skills.

The FMS testing protocol was adopted from that of O'Brien et al. (2016a). Children were evaluated in their class groups of approximately 25-30 children. Testing was conducted in large indoor sports halls. On arrival to the hall, children were each given a sticker with

a pre-assigned code on it to ensure anonymity. The class group was sub-divided into four stations, at each of which a number of FMS were tested:

- (1) run, leap, hop, gallop, slide
- (2) catch, throw, roll
- (3) strike, kick
- (4) dribble, horizontal jump (Figure 3.1).

Two evaluators were assigned to each station. One evaluator, Evaluator A, provided children with a silent demonstration of the first skill to be tested. Subsequently, children performed one familiarisation followed by two test trials, with both test trials recorded on a video camera (Canon Legria HF R606) by Evaluator B who also spoke the child's code and trial number into the camera as the trials were performed. (The cameras recorded at a frequency of 25 frames per second and were set up in the sagittal plane for all skills except the dribble and strike for which they were set up in the frontal plane.) This was repeated for all skills at each station. When all of the skills at each respective station were completed, the groups simultaneously rotated to the next station. This process was repeated until all 12 skills had been completed by all children.

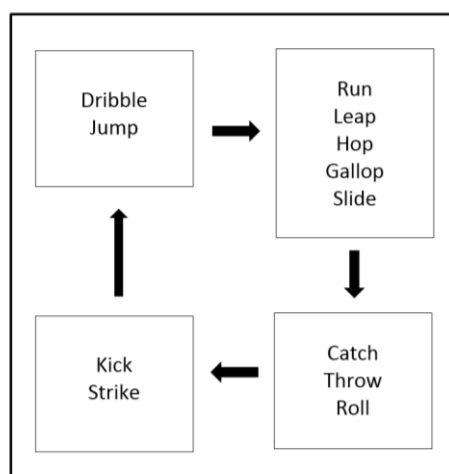
### FMS Scoring

The recordings of the test trials were uploaded to a password protected laptop and analysed retrospectively using the protocol developed by Ulrich (2000). Each skill consisted of 3-5 performance criteria. A score of 1 was awarded if a criterion was performed correctly, while a score of 0 was awarded if it was absent. This procedure was carried out for each criterion across the two test trials. The two test trial scores were summed to give a raw skill score. The raw skill scores of the locomotor skills were summed to give a locomotor subset score (LOCO: range 0-48) while the raw skill scores of the object-control skills were summed to give an object-control subset score (OC: range 0-48). Subset scores were summed to give an overall FMS score (TOTAL FMS: range 0-96) (Ulrich, 2000).

FMS scoring was conducted by two ‘FMS evaluators’; this postgraduate researcher and another member of the Project Spraoi Research Team who was also conducting PhD research in the area of FMS. Prior to the scoring of the pre-intervention data, both FMS scorers completed 2 x 2-hour FMS scoring training sessions with a Research Mentor with over 6 years’ experience in FMS assessment and protocol. Intra- and inter-rater reliability between the ‘FMS evaluators’ was measured using 10% of the collected sample at each time point (i.e. pre- and post-PA intervention, and pre- and post-FMS intervention) and calculated using the following formula:

$$\frac{\text{agreements}}{\text{agreements} + \text{disagreements}} \times 100 \quad (\text{Thomas et al., 2011})$$

Intra- and inter-reliability scores for all 12 FMS exceeded the 85% threshold required to demonstrate reliability (Thomas et al., 2011).



**Figure 3.1:** FMS testing layout

### **3.3.2 Physical Measures**

Physical measures taken were height, mass, WC (2014/2015 only), heart rate and BP. To ensure reliability between measurements, the same evaluators, where possible, administered the same test during both pre- and post-intervention testing periods. Testing took place in a quiet room in the school that had been specifically reserved for

such testing sessions. Groups of 5-8 children were called to the testing room at a time. All physical tests were carried out during the one visit (i.e. approximately 15 minutes in duration). Children were requested to remove their shoes and school jumpers prior to the commencement of testing.

#### Height and Body Mass Measurement

Height was measured to the nearest 0.1cm using a Leicester portable height scales. Children were instructed to stand with their heels, shoulders and back of their head touching the vertical pole of the height scales, with their head looking straight ahead. Height was measured on inspiration (ISAK, 2001). Children were asked to step out from the instrument and the process was repeated a second time. If the first two measurements differed by greater than 0.5cm a third measurement was taken (Coppinger et al., 2016).

Body mass was measured to the nearest 0.1kg using a Tanita WB100MZ portable electronic scale. Children were requested to step onto the scales and look straight ahead while remaining stationary until the test administrator had recorded the reading. Following the first measurement, children stepped off the scales and then back on so that a second measurement could be taken. Two measurements were recorded (unless the first two differed by greater than 0.5kg, in which case a third measurement was taken) (Coppinger et al., 2016).

#### WC Measurement

WC was measured using a non-stretch Seca 200 measuring tape. Children were instructed to stand up straight, hands by their side, feet together and look straight ahead. Measurements were taken from the right side of the child as the circumference of the narrowest part of the abdomen between the lower costal border and the top of the iliac crest, perpendicular to the long axis of the trunk (Coppinger et al., 2016). Children were instructed to inhale and then exhale, with measurements taken upon exhalation. Two measurements were taken, with a third taken if the first two differed by more than 0.5cm (Coppinger et al., 2016).

#### Heart Rate and BP Measurement

Heart rate (measured to the nearest beat per minute) and BP (SBP and DBP) (measured to the nearest mmHg) were measured using an Omron M2 Basic Auto Blood Pressure Monitor. Measurements were taken with the cuff positioned on the upper left arm of the child who sat relaxed and quietly with their feet flat on the ground and the left arm raised on a pillow to heart level. BP was measured to  $\pm 5.0$  U and  $\pm 10$  mmHg. Prior to measurement, children sat quietly for the duration of the time it took to measure the child ahead of them (approximately 5 minutes). Two measurements were taken, with a third taken if the first two differed by 10bpm (heart rate) or 10mmHg (BP).

The mean of the two collected measurements (or alternatively the mean of the two closest measurements when a third measurement was required) was calculated for each measure (i.e. height, mass, WC, heart rate and BP). This values was subsequently used in the analysis. BMI and WHtR were calculated using the following formulas:

$$\text{BMI} = \frac{\text{body mass (kg)}}{\text{height squared (m}^2\text{)}}$$

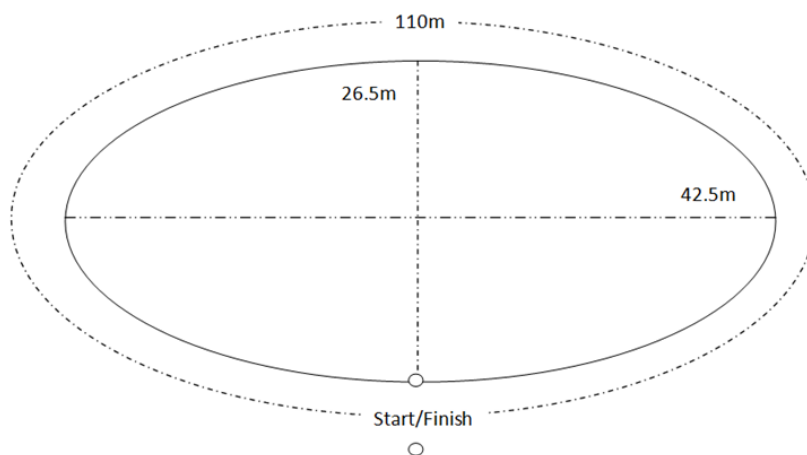
$$\text{WHtR} = \frac{\text{waist circumference (cm)}}{\text{height (cm)}}$$

The Excel add-in LMS-growth programme (version 2.77) was used to calculate standard deviation scores and percentiles from the British 1990 child growth reference data for age- and sex-specific percentiles of BMI (Cole et al., 1995), WC (McCarthy et al., 2001) and systolic and DBP (Jackson, Thalange, & Cole, 2007).

### CRF Measurement

CRF was measured using the 550m run/walk test (Albon et al., 2010) which has been found to be a valid measure of CRF among children (Hamlin et al., 2014). The test was conducted under similar environmental conditions at each time point (i.e. in the same place on dry, relatively windless days). An oval loop of 110m (26.5m x 42.5m) was laid out (using a calibrated rope) on a large, dry, flat, grass area (Figure 3.2). Children completed a warm up prior to testing. The warm up consisted on one lap of the 110m

loop which was completed by jogging (approximately 20m), high knees (approximately 20m), heel flicks (approximately 20m), skipping (approximately 20m) and sprinting (approximately 30m). Groups of 12-15 children were tested at the same time. The group of 12-15 was subdivided into smaller groups of 3-4 and each group assigned to an evaluator. Children were instructed to complete 5 laps of the marked track as quickly as possible. Evaluators started their groups one at a time. For instance, the first group of 3-5 children (Group A) started when evaluator A said 'Go' and started their stopwatch. When group A were a sufficient distance ahead (approximately 20m), evaluator B said 'Go', started their stopwatch and the second group of 3-5 children (Group B) started and so on until all groups had been set off. On completion of each lap, children were informed of how many laps they had left. The time taken to complete the 550m of each child was measured using a stopwatch and recorded to the nearest second. Data (550m time) was not recorded if a child stopped for more than 5 seconds or if they did not complete the 550m distance. Time taken to complete the 550m was converted from minutes and seconds, into total seconds. Age- and sex-specific 550m run standard deviation scores were calculated using the run centile curves developed by 'Project Energize' evaluation data (Rush & Obolonkin, 2014).



**Figure 3.2:** 550m run/walk test setup

### PA Measurement

PA was measured using tri-axial ActiGraph GT3X accelerometers (Fort Walton Beach, FL, USA). Data collected in the vertical axis was used for analysis. Migueles et al. (2017) (who carried out a review of methods used for the collection of PA data using GT3X

and GT3X+ accelerometers among children and adolescents) found that the hip was the most commonly used placement site for the accelerometers (90% of the included studies) and so children in this research wore the accelerometers for 7 consecutive days on their right hip for all waking hours, except while in water (e.g. swimming, shower/bath). ActiLife software (version 6.13.3) was used to analyse the data. Data were collected and stored in 5-second epochs and were then reintegrated into 15-second epochs. ActiLife software subsequently scaled this 15-second data up to 60-second data (i.e multiplied the 15-second value by 4). The cut-points of Evenson et al. (2008) which were developed using data that were collected in 15-second epochs were also scaled up to their 60-second equivalents in ActiLife. The scaled up version of Evenson et al.'s (2008) cut-points (Table 3.3) were then used to classify PA into different intensities.

In line with recommendations of Migueles et al. (2017), valid wear time was defined as a minimum of 4 days (3 weekdays and 1 weekend day) of at least 10 hours of wear time (Riddoch et al., 2004). Non-wear times were identified as 20 minutes of consecutive zeros (Esliger, Copeland, Barnes, & Tremblay, 2005). This definition for non-wear time (i.e. 20 minutes of consecutive zeros) was found to be the most commonly used in studies that collected PA data using GT3X and GT3X+ accelerometers among children and adolescents (Migueles et al., 2017). The first day of accelerometer wear time was removed from the data-set to allow for subject reactivity (Esliger et al., 2005). In their review, Migueles et al. (2017) found that the PA cut-points of Evenson et al. (2008) were the most commonly used cut-points for PA intensity classification and so Evenson et al.'s (2008) cut-points were used to calculate time spent in PA of differing intensities (Table 3.3). The PA variables calculated were mean daily light PA, mean daily moderate PA, mean daily vigorous PA, mean daily MVPA and mean daily total PA. PA variables were measured for weekdays, weekend days and total week time periods.



**Table 3.3:** 60-second epoch equivalents of Evenson et al's (2008) cut-points that were used for PA intensity classification

<b>PA intensity</b>	<b>Cut-points (counts per minutes)</b>
Light PA	101-2295
Moderate PA	2296-4011
Vigorous PA	≥4012
MVPA	≥2296
Total PA	≥101

In October 2014, a total of 48 randomly selected children (intervention n=32; control n = 16) (22%) received accelerometers due to limited accelerometer availability. In September 2015 (prior to the FMS intervention) owing to a greater availability of accelerometers (compared to the pre-intervention testing of the 2014/2015 PA intervention), a total of 247 children received accelerometers. Only those who met the wear time criteria of a minimum of 600 minutes on three weekdays and one weekend day at both pre- and post-intervention were included in the analysis used to examine the effectiveness of the interventions.

### **3.3.3 Perceived FMS Competence (pre- and post-FMS intervention only)**

The Pictorial Scale of Perceived Movement Skill Competence (Barnett, Ridgers, Zask, et al., 2015) was used to evaluate children's perceived FMS competence in the 12 FMS (6 locomotor: run, leap, hop, gallop, slide, jump and 6 object-control :catch, throw, roll, kick, strike and dribble) that were assessed using the TGMD-2. The Pictorial Scale of Perceived Movement Skill Competence has been validated as a measure of perceived FMS competence among children from a number of different countries (Barnett, Ridgers, Zask, et al., 2015; Lopes et al., 2016; Valentini et al., 2018) and has good test-reliability (ICC=0.83) (Lopes et al., 2016) and adequate internal consistency (alpha range=0.60–0.81) among children (Barnett, Ridgers, Zask, et al., 2015; Lopes et al., 2016).

This test was administered to one child at a time and lasted approximately 3-5 minutes. Children were presented with cartoon images of two children performing the given FMS. One child was competent at performing the skills and one child was not (Figure 2.4). Children were asked whether they felt they were more like the child who was 'good' at

performing the skill or the child who was 'not so good' at performing the skill. Depending on their response, children were subsequently asked whether they felt they were 'very good' or 'pretty good' at performing the skills or alternatively 'not very good' or 'sort of good' at performing the skill. Perceived competence scores for each skill ranged from 1 to 4 (1=not very good, 2=sort of good, 3=pretty good, 4=very good) with higher scores indicating higher perceptions of skill competence.

### **3.4 PA Intervention (2014/2015)**

This section provides an overview of the design, content and delivery of the PA intervention that was implemented in the two intervention schools over a 6-month period during the academic year 2014/2015. The Energizer's role in the delivery of the intervention is also outlined.

Prior to the commencement of this project, the Energizers and other established members of the Project Spraoi Research Team met with the principal and teachers of the intervention schools (for approximately one hour) to identify PA and healthy eating/nutrition-related aspects of their school life that they felt were satisfactory (e.g. the school may have been well equipped with bibs, tennis ball and basketballs) and also those aspects that they felt were not (e.g. the children were not permitted to go out to yard for break time). For the purpose of the needs analysis, teachers were divided into small groups with an evaluation sheet distributed to each group (Appendix E.2). This evaluation sheet was originally designed and questions were developed by Sport Waikato for use in Project Energize. It has also been used previously in Project Spraoi. The sheet consisted of six questions which the groups were required to answer.

1. *Physical activity: What do we do well?*
2. *Physical activity: What would we like to improve on?*
3. *Physical Activity: How do you think the Energizer can assist you in improving physical activity?*
4. *Nutrition: What do we do well?*

5. *Nutrition: What would we like to improve on?*

6. *Nutrition: How do you think the Energizer can assist you in improving nutrition?*

Following this activity, one of the Project Spraoi Research Team members led a whole group discussion based on these questions. Issues identified and suggested solutions were recorded by the Energizer who then tailored the intervention in an attempt to meet the needs of each individual school. For example, the vast majority of teachers felt they lacked confidence in teaching the gymnastics strand of the physical education curriculum. A solution suggested was that the Energizer would organise a professional development workshop related to gymnastics. Based on this identified need, a gymnastic-based workshop was subsequently organised by the Energizer. This workshop was delivered by a Project Spraoi Research Team member who had vast experience in practicing gymnastics and teaching gymnastics modules to university students training to be secondary school physical education teachers. The workshop was a practical session of suitable gymnastics-related activities that teachers could subsequently use during their own PE classes. Teachers had the opportunity to ask questions relating to specific issues they may have had in relation to the teaching of gymnastics at this workshop e.g. what are the key teaching points of the forward roll? At what age should you allow children to try forward rolling? The Energizer also modelled gymnastics-related PA sessions as part of the intervention during the school year.

#### Intervention Content

The PA intervention was modelled on Project Energize and the socio-ecological model provided a framework for the intervention (Table 3.6). The PA intervention was delivered from November 2014 to April 2015 (6 months) in two intervention schools (one urban single-sex boys and one urban single-sex girls). The intervention was delivered to each intervention school by an Energizer who was a postgraduate researcher with an undergraduate degree in Sport and Exercise Sciences with extensive experience in delivering PA sessions to primary school-aged children. Before the delivery of the intervention, Energizers attended numerous training workshops with members of the Project Spraoi Research Team who had experience (ranging from 1-2 years) in delivering similar interventions to primary school children. Energizers also delivered

sample practical PA sessions to third level students in preparation for the delivery of the intervention in their respective schools. Throughout the intervention, Energizers participated in conference calls to members of Project Energize (New Zealand) during which ideas and resources were shared. Energizers also met regularly with the other members of the Project Spraoi Research Team to share ideas, discuss issues that may have arisen and to share resources.

The intervention content is summarised in Table 3.4. The intervention involved the delivery of 2 x 25-minute 'huff and puff' sessions to each class each week in the school. 'Huff and puff' sessions involved high intensity games and activities that encouraged children to engage in moderate-to-vigorous levels of PA in a fun and enjoyable environment. These sessions were delivered in the school sports hall, on the school yard or in the classroom (on rainy days when the hall was unavailable). Given that children spend more than one third (5 hours 40 minutes) (Irish National Teacher's Organisation, 2017), of their waking day (13-15 hours) (Hirshkowitz et al., 2015) in school, teachers were encouraged to provide children with the opportunity to engage in at least one-third of the recommended daily 60 minutes of MVPA (i.e. 20 minutes) during class time on the remaining 3 school days. Notably, it was not required that this 20 minutes be accumulated in the one session; smaller more frequent activity breaks were also encouraged (e.g. 4 x 5 minute activity breaks throughout the school day). Energizers supported teachers by providing printed games resources (Appendix C.1), links to online interactive dance resources, organising access to local university facilities throughout the year, as well as modelling PA sessions and organising a one hour professional development workshop in the area of gymnastics . Energizers also set up a whole school PA initiative called the 'Stride for 5' to further promote children's engagement in PA. The aim of this initiative was for every student in a class to run continuously for 5 minutes. The 'Stride for 5' challenge began with children attempting to run continuously for 1 minute around a marked area of the school hall/yard. If the class successfully achieved one minute of continuous running (without any child stopping or walking), they progressed to the next level i.e. to try to run continuously for 2 minutes. Classes could only progress one level per week and it was required that the Energizer be present to witness the successful attempt. If any child stopped or walked at any stage during an

attempt, the class remained at that level. A ‘Stride for 5’ poster (Appendix C.2) was hung in the school sports hall to monitor the progress of each class throughout the challenge. Classes were encouraged to practice for their next attempt throughout the school week (with their class teacher) as well as at home with a friend or a member of their family. Classes that had achieved five minutes of continuous running by the end of the initiative (approximately 6 weeks or alternatively the first class to complete the challenge) were awarded with a small prize (e.g. homework passes, activity day) and their class was positioned at the top of the ‘Stride for 5’ poster.

The intervention also included the delivery of 2 x 20 minute healthy eating lessons during the 6 month intervention period. One of these lessons was based on popular drinks and involved discussions relating to the key ingredients, nutritional value and sugar content of these drinks. The other lesson was based on the food pyramid. Posters and laminated cards promoting PA and healthy eating were made available to schools and fridge magnets were distributed to children to bring home (to further emphasise the importance of PA and healthy eating at both school and home) (Appendix C.3).

**Table 3.4:** A summary of the PA intervention content

<b>Intervention Component</b>	<b>Details</b>	<b>Dose</b>
Energizer-led ‘huff and puff’ PA sessions	High intensity games-based PA sessions were delivered in the schools	2 x 25 minutes each week per class
Encouragement and support for teachers to deliver 20 minutes MVPA (on the days without an Energizer-led huff and puff session)	<ul style="list-style-type: none"> <li>Printed games resources were developed and distributed to teachers</li> <li>Links to online interactive dance resources were sent to teachers.</li> <li>Access to local university sports facilities was organised.</li> </ul>	Throughout the year
Teacher professional development	A one hour professional development workshop in the area of gymnastics was organised.	1 x 1 hour workshop
PA initiative	The Stride for 5 was set up (see page 118)	This initiative was run for approximately 6 weeks
Healthy eating lessons	<ul style="list-style-type: none"> <li>One sugary drinks based lesson</li> <li>One lesson based on the major food groups of the food pyramid</li> </ul>	2 x 20 minutes during the 6 month intervention

The control school was instructed to follow their typical PE programme. According to the Department of Education and Skills, it is recommended that primary schools engage

in at least one hour of physical education per week (Department of Education and Science, 1999).

### **3.5 FMS Intervention (2015/2016)**

This section provides an overview of the FMS intervention that was delivered to the two intervention schools over a 26-week period during the academic year 2015/2016. The underlying framework, the evidence-based recommendations that guided the intervention and the multi-component nature of the intervention are outlined. The section also outlines the role of the Energizer in the delivery of the intervention and gives a detailed account of resources that were developed and used as part of the intervention.

The socio-ecological model presented by McLeroy et al. (1988) provided the framework for this intervention (Table 3.5). In accordance with recommendations by Riethmuller et al. (2009), that outline that FMS interventions should (i) be delivered by both the researcher and teachers and (ii) involve parents so that knowledge from the intervention can be transferred from the school to the home setting, the intervention was designed to have both school-and home-based components.

**Table 3.5:** An outline of how the socio-ecological model’s framework guided the interventions

Factor	Strategies implemented	Desired result
Intrapersonal	<ul style="list-style-type: none"> <li>• Delivery of fun, high-intensity PA sessions</li> <li>• Encouragement and support for teachers to facilitate at least 20 minutes PA throughout the school day</li> </ul>	<ul style="list-style-type: none"> <li>• Increased enjoyment of PA</li> <li>• Increased fitness levels</li> <li>• Improved FMS</li> <li>• Increased knowledge and awareness of the importance of PA and healthy eating</li> </ul>
Interpersonal	<ul style="list-style-type: none"> <li>• Distribution of information sheets about Project Spraoi home to parents/guardians</li> <li>• Encouraging practice and engagement of PA with family members and friends outside of school (Stride for 5, homework manuals (Appendix D.3)</li> <li>• Distribution of health-promoting fridge magnets to families (Appendix C.3)</li> </ul>	<ul style="list-style-type: none"> <li>• Increased knowledge and awareness among parents/guardians and families of the importance of PA and healthy eating.</li> </ul>
Institutional	<ul style="list-style-type: none"> <li>• Encouraging and supporting teachers to facilitate at least 20 minutes MVPA throughout the school day.</li> <li>• Delivering of model PA sessions.</li> <li>• Delivering a gymnastics workshop.</li> </ul>	<ul style="list-style-type: none"> <li>• A new habit in school in which teachers would allow children to engage in a minimum of 20 minutes MVPA daily during the school class time.</li> <li>• Increase teacher competence and confidence in the delivery of PE/PA sessions.</li> <li>• Educate teachers in the how to maximise participation and activity levels during PA sessions.</li> </ul>
Community	<ul style="list-style-type: none"> <li>• Creation of link with the local universities for the use of resources.</li> </ul>	<ul style="list-style-type: none"> <li>• Established relationship between school and community.</li> </ul>
Public Policy	<ul style="list-style-type: none"> <li>• Presentation of intervention findings to local authorities and at PA-/PE-related conferences.</li> </ul>	<ul style="list-style-type: none"> <li>• Acknowledgement by local and/or national authorities that such an intervention is warranted and effective among Irish primary school children.</li> <li>• Provision of funding to delivery such an intervention in a larger number of schools.</li> <li>• The inclusion of such an intervention in the Irish primary school curriculum.</li> <li>• Adaptation of the current teacher training courses, teacher continuous professional development workshops and sports coaching courses based on the evidence-based findings of the research.</li> </ul>

Components included in the FMS intervention were modelled on some of those used in interventions (Cohen, Morgan, Plotnikoff, Callister, et al., 2015; Mitchell et al., 2013; O'Brien et al., 2013) that reported a positive intervention effects for FMS, PA, fitness and/or adiposity levels. For example, the FMS intervention designed in the current research included the delivery of specialist-led PA sessions to children and the delivery of professional development workshops to teachers as in the Youth Physical Activity Towards Health (Y-PATH) (O'Brien et al., 2013). As the Energizer-led PA sessions delivered in the current intervention were to be delivered during the scheduled PE time, schools requested that these sessions be linked to the Irish PE curriculum (Department of Education and Science, 1999). As a result, FMS-based lesson plans were developed to align with the six strands of the Irish Primary PE curriculum; athletics, games, dance, gymnastics, aquatics and outdoor adventure. For example, the run, throw and jump were primarily incorporated into lessons delivered under the 'athletics' strand, the slide and hop into lessons of the 'dance' strand, the catch, roll, dribble, kick, gallop and strike primarily under the 'games' strand, the leap as part of the 'gymnastics' strand. While skills were primarily delivered as part of lessons to align with a specific strand, skills were also incorporated into lessons of other strands e.g. the throw was primarily delivered as part of the 'athletics' strand. However, it may also have been included in lessons delivered under the 'games' strand.

### Intervention Content

The FMS intervention was carried out across 26 academic weeks between October 2015 and May 2016. The FMS intervention content is summarised in Table 3.6. The intervention was primarily delivered by the 'Energizer' with the classroom teachers also playing a role in the delivery of the programme. The FMS intervention was multi-component and consisted of (i) the delivery of FMS-based lessons (ii) the dissemination of FMS posters and FMS homework manuals (iii) professional development workshops and resources, (iv) an FMS activity break initiative and (v) other PA promoting initiatives (e.g. 'Stride for 5', 'Kilometre Challenge', 'PE Student of the Week', 'Paper Rush' and 'Active Agents'). In addition, teachers were encouraged to engage children in a minimum of 20 minutes of MVPA during every school day (other than those on which the FMS lessons were held).



**Table 3.6:** A summary of the FMS intervention content

<b>Intervention Component</b>	<b>Details</b>	<b>Dose</b>
Energizer-led FMS-based lessons	<p>Lessons involved:</p> <ul style="list-style-type: none"> <li>• a huff and puff activity</li> <li>• FMS instruction feedback and practice</li> <li>• An FMS-based activity/task/game</li> </ul>	2 x 25 minutes each week per class
FMS posters	Posters depicting correct technique and teaching cues for an FMS were hung in each classroom	Posters were changed (to those of a new skill) every 2 weeks
FMS homework manuals	FMS homework manuals contained small images of the FMS posters and numerous age-appropriate FMS-based activities. An activity record sheet was included in the back of the manual where children recorded what activities they completed and how difficult they found the activity to complete. At the end of each week, the Energizer collected the homework manuals and rewarded children with 'homework points' for each completed activity. Small prizes were distributed to those who achieved the most homework points at the end of each school term.	FMS homework was given from Monday-Thursday each week
Teacher professional development	<ul style="list-style-type: none"> <li>• Professional development workshops were delivered</li> <li>• FMS teacher manuals were distributed to teachers</li> </ul>	2 x 90 minutes workshops (1 for gymnastics and 1 for FMS)
FMS activity break charts	These charts were calendar like charts that were hung in each classroom. The charts instructed children to take at least 6 short activity breaks each day. During each break, children completed one huff and puff activity (e.g. sprinting on the spot for 10 seconds) and also completed a number of correct trials of an FMS (e.g. 10 catches of a tennis ball with a partner). Additional PA engaged in by the class was also recorded on this chart. Classes received one point for each completed set of pre-specified activities and one point for each additional PA minute they accumulated during class time each day. These charts were collected by the Energizer at the end of each week, points were added up and scores were posted to a leader board. At the end of each term, the teacher and children in the most active class (based on the points scored) were awarded a certificate and a small prize.	At least 6 times during every school day
Other PA initiatives	<p>These included:</p> <ul style="list-style-type: none"> <li>• The Stride for 5</li> <li>• The Kilometre Challenge</li> <li>• The Paper Rush</li> <li>• PE Student of the Week</li> <li>• Active Agent</li> </ul> <p>(see text for more details)</p>	The Stride for 5, the Kilometre Challenge and the Paper Rush were run for approximately 6 weeks each. The PE Student of the Week and the Active Agent initiative were run throughout the school year.
Encouragement and support for teachers to deliver 20 minutes MVPA (on the days without an Energizer-led FMS-based session)	<ul style="list-style-type: none"> <li>• Printed games resources were developed and distributed to teachers</li> <li>• Links to online interactive dance resources were sent to teachers.</li> <li>• Access to local university sports facilities was organised.</li> </ul>	Throughout the year

FMS-based lesson plans (Appendix D.1) were developed, and delivered to each class during 2 x 25 minute sessions each week for 26 weeks. These sessions were delivered by the Energizer. The classroom teachers assisted in a number of ways such as organising equipment, putting children into groups, leading some games and activities, providing instruction and feedback to children and often participating in the lesson themselves if children required partners for FMS practice. Sessions typically involved three parts: (i) a 'huff and puff' activity, (ii) FMS instruction, feedback and practice and (iii) an FMS-based activity/task/game. With the aim to develop the 12 FMS over the intervention period, each skill was the primary focus of the intervention for the duration of two consecutive weeks. The final two weeks of the intervention involved sessions that focused on multiple FMS, with the emphasis placed on those skills that appeared to be the most difficult to master for the children in the given schools. These skills were the catch, dribble and hop.

Due to the packed Irish primary school curriculum and the emphasis on academic subjects in the intervention schools, FMS lessons replaced the PE time in the single-sex girls' school while in the single-sex boys' school, one of the lessons replaced half of the allocated PE time and the other 25-minute session was an additional session scheduled every week.

A series of FMS posters were designed and developed for each of the 12 FMS (Appendix D.2). These posters were hung in each classroom during each skill's 2-week focus period. Posters consisted of drawings of cartoons correctly performing a specific FMS, in addition to relevant teaching cues (those that were used in the lessons) for the given skill.

FMS homework manuals were developed (Appendix D.3) and distributed to all children in the intervention classes. FMS homework manuals contained small images of the FMS posters (which depicted correct FMS technique and appropriate cue words) and multiple age-appropriate activities, with activities for all skills levels included. Many of the included activities were designed so that they could be performed alone or with a partner(s) to encourage parents and family members to also participate in the activities.

FMS homework was prescribed each week by the Energizer and distributed by the classroom teacher each night. The homework was based on the skill in focus at that time. An activity record section was included at the back of the manual. Children/parents were instructed to record their activities each night, and also to indicate whether they found the tasks 'easy', 'ok' or 'hard' in this section. At the end of each week, the classroom teachers collected the manuals and the Energizer awarded 'homework points' for each recorded exercise. Small prizes (e.g. tennis racquet set, bouncy ball) were distributed to the children who achieved the most homework points at the end of each school term.

Professional development opportunities for teachers were provided in the form of two practical workshops (one FMS-based and one gymnastics-based) as well as associated printed resources (Appendix D.4). The practical workshops, which lasted approximately 90 minutes, were delivered by the Energizer and other members of the Project Spraoi Research Team. The FMS workshop consisted of the demonstration of correct technique for each of the FMS, and provided an opportunity for teachers to practice and obtain feedback on their own performance of each of the skills. A variety of appropriate fun, age-appropriate tasks suitable for their classes, appropriate cues and instructions for the development of FMS, common errors among children when performing FMS and also potential ways to eliminate these errors were also discussed. The gymnastics workshop consisted of a variety of basic gymnastics-related activities that could be adapted and used among children of a wide age range. The workshops also provided an opportunity for the teachers to speak to the Energizers and discuss any PA related issues, concerns or merely ask any questions they may have had about the intervention, FMS development or relating to PA or nutrition. FMS teacher manuals were designed and distributed to each classroom teacher. These manuals included a detailed description of how to correctly perform each FMS, images of the FMS posters depicting correct technique and cue words, common errors, tips when teaching the skills as well as appropriate FMS-based activities and variations of these (to allow differentiation for a broad age and skill range).

To encourage teachers to allow children to engage in as much PA as possible throughout the school day (outside of the FMS-based lessons), FMS Activity Break Charts were designed (Appendix D.5). The charts were presented as weekly calendar-like pages that were hung in the classroom each week. The charts instructed children to take at least 6 short activity breaks each day. During each break, children engaged in one 'huff and puff' activity (such as sprinting on the spot for 10 seconds) and also practiced the correct technique of an FMS (e.g. 10 catches of a tennis ball with a partner). Different 'huff and puff' activities were prescribed on the chart each day while the FMS skill remained the same for its 2 week period in focus. Each time the pair of activities was completed, a tick was drawn on the chart reflecting the successful completion of the activities. Each tick equated to one point for the class. Any additional PA time (i.e. PA outside of PE, the Energizer-led sessions and the prescribed FMS activity breaks) was also recorded in minutes, with each minute worth a score of 1 point. Each week, the FMS activity charts were collected from all of the classes for review. The amount of PA accumulated was calculated for each class and recorded on a school leader board each week. At the end of each term, the children and teacher in the class with the most points i.e. the most active class, were presented with a certificate (Appendix D.6) and a small prize (e.g. homework passes (Appendix D.7), a ruler, pen, a PA fun day). All classes returned to zero points at start of each term.

Other PA initiatives carried out to promote PA and/or CRF included the 'Stride for 5' (see page 118), 'the Kilometre Challenge', 'the Paper Rush', 'PE Student of the Week' and the selection of the 'Active Agent'.

*The Kilometre Challenge:* A route of set distance was marked out on the school yard using cones (e.g. a 100m loop). Children were required to complete 10 laps of the route to complete a distance of one kilometre. All children began the challenge together on the start line. The aim of this challenge was to complete the one kilometre distance as fast as possible. Each child's kilometre times were measured and recorded. On the Energizer's next visit to the school (usually the next FMS-based lesson), the Energizer gave each child a score card with their own kilometre time on it (Appendix D.8). Children could then challenge themselves to improve on this time in the future. This was

repeated each time the children attempted the one kilometre challenge. Emphasis was placed on children improving on their own time irrespective of what time anyone else had. The 'Kilometre Challenge' initiative was run for 6 weeks. At the end of the 6 weeks, each child received a final score card showing their initial and final and/or best 1 kilometre time(s).

*The Paper Rush:* A circular loop (of approximately 20m) was marked out in the school yard/hall. One empty cardboard box was placed at one end of the hall/yard while one cardboard box full of paper balls (scrunched up newspaper balls wrapped in sellotape) was placed at the other end. The aim of the challenge was for the class to transport as many paper balls as possible from one box to the other in a given time. While all children ran at the same time, they were only permitted to transport one paper ball at a time. Each class in the school was given the same amount of time to complete the 'Paper Rush' (e.g. 3 minutes). At the end of the allotted time, the paper balls that had been transported were counted and the class score was recorded on a scoreboard in the sports hall. The Paper Rush was typically attempted at the start of each FMS-lesson. The initiative lasted for 6 weeks.

*PE Student of the Week:* This initiative was designed to promote PA and encourage children to try their best in all PA-related activities throughout the school week. At the end of each week, each class teacher selected a 'PE Student of the Week'. The 'PE Student of the Week' was chosen based on the children's effort to improve their FMS, their enthusiasm and willingness to learn during PE and PA sessions as well as their efforts to promote PA/FMS in the classroom, on the yard and throughout the school. Each week the selected 'PE Student of the Week' was awarded a special certificate (Appendix D.9). This certificate was placed on the outside of the classroom door for the duration of the following week, during which time the 'PE Student of the Week' assumed the role of an 'Active Agent' (see below). The certificate was then brought home when the next 'PE Student of the Week' was selected. This initiative ran throughout the school year.

*Active Agent:* 'Active Agents' were specially selected PA enthusiasts that put a great effort into any PA-related activity they engaged in and/or promoted throughout the school. Each 'Active Agent' wore a special badge that acknowledged their role. This role involved ticking the FMS Activity Break Chart, writing in additional PA that the class engaged in, reminding and encouraging the teacher to take classroom and outdoor PA breaks as well as reminding the teacher to distribute FMS homework. The 'Active Agent' assisted with providing demonstrations during the FMS-based lessons during their week in the role and was the one selected to complete any PA-related business for their class.

The control school was instructed to follow their usual PE programme. The Department of Education and Skills recommended that primary schools engage in at least 60 minutes of physical education per week (Department of Education and Science, 1999).

### **3.6 Process Evaluation**

Process evaluation of the PA intervention was carried out on the 9<sup>th</sup> February 2015 in a meeting between the Energizer and three other members of the Project Spraoi Research Team. Teachers were divided into small groups (approximately 3-4 teachers per group) and were asked to answer three questions (Appendix F.1). The questions were:

1. *What aspects of the intervention have worked well so far?*
2. *What are the barriers to completing 20 minutes physical activity with your class daily?*
3. *What ways can we (the Energizer and/or the Project Spraoi Research Team) help you and your class achieve 20 minutes physical activity each day?*

The groups were given approximately 10 minutes to write down their answers. The questions and answers were then discussed among the group as a whole in an attempt to identify areas that required more attention and also the barriers and facilitators of PA across the school day. Adaptations to the intervention were then made depending on the outcomes of this meeting. For example, teachers highlighted that 'providing ideas

for quick and easy activities inside and outside the classroom' and 'help with gymnastics' may help teachers achieve 20 minutes of PA every day. In an attempt to address these responses, the Energizer designed and developed a games manual of indoor and outdoor games/activities which was then distributed to teachers and also organised a gymnastics workshop with a member of the Project Spraoi Research Team who had over 13 years' experience delivering gymnastics teacher training to third level PE student teachers.

Process evaluation of the FMS intervention included (i) teacher questionnaires (one completed at mid-programme and one at the end of the programme (Appendix F.1), (ii) a write and draw activity (Appendix F.2) completed by children from the intervention schools, and (iv) interviews with children from the intervention schools. The mid-programme questionnaire which was completed by 24 class teachers consisted of 12 statements which teachers were instructed to respond to using a 5-point Likert scale (1=strongly agree, 2=agree, 3=undecided, 4=disagree, 5=strong disagree). The statements related to the feasibility of the intervention, teacher engagement, class behaviour following PA sessions, teachers perception of whether there was an improvement in their students' fitness and eating habits, adaptations to the teachers' own behaviours and knowledge as a results of the intervention. The questionnaire also consisted of two open ended questions, one which aimed to identify positive aspects of the intervention and the other that aimed to identify aspects of the intervention with potential for improvement. The end of programme questionnaire which was completed by one principal and 22 class teachers consisted of 5 statements to which teachers were instructed to respond to using a 5-point Likert scale. These statements related to the enjoyment, feasibility and future of the intervention. The questionnaire also involved a quality rating of the nutrition content, PA content and Energizer competence in which teachers were asked to rate each of these aspects on a 5-point scale (1=very good, 2=good, 3=OK, 4=poor, 5=very poor), and four open ended questions. These questions were designed to identify aspects of the intervention with the potential for improvement, the part of the intervention that teachers enjoyed most in addition to barriers and facilitators faced by the teacher when implementing the intervention. Printed versions of the questionnaires were distributed to teachers and collected from

those who completed them at the respective time-points (mid-programme and end of programme).

Write and draw activity sheets (Appendix F.2) were distributed to all children in the senior infant, 1<sup>st</sup>, 4<sup>th</sup> and 5<sup>th</sup> classes in the intervention schools. Children were instructed to draw a picture and write about what the intervention meant to them. Two children from each of the class were also randomly selected to participate in an interview. Interviews were carried out individually outside the classroom door and lasted approximately 5 minutes. Interview questions related to children's completed write and draw activity, the intervention's Energizer-led sessions, the school environment and how the intervention is delivered outside of the Energizer-led sessions and FMS.

### **3.7 Statistical Analysis**

All data were analysed using SPSS version 22. Children in senior infants and 1<sup>st</sup> class were categorised as '6 year olds' while children in 4<sup>th</sup> and 5<sup>th</sup> class were categorised as '10 year olds'. Analysis was carried out separately for the 6 and 10 year old groups for all variables except PA. Due to the limited sample size from which valid PA data was collected, children from both age categories were grouped together for the analysis of this data. For the evaluation of the interventions, only children who had both pre- and post-intervention data (for each of the measured variables) were included in the analysis. Means, standard deviations and frequencies are used to summarise the data. Data were assessed for normality. Pearson (when data was normally distributed) and Spearman (when data was not normally distributed) correlations were used to investigate the relationship between FMS variables and markers of health. Correlations were classified as recommended by Zhu et al. (2016) as non-existent ( $r=0-0.19$ ), small ( $r=0.20-0.39$ ), moderate ( $r=0.40-0.59$ ), moderately high ( $r=0.60-0.79$ ) or high ( $r\geq 0.80$ ) (Zhu et al., 2012). When FMS (GMQ) was significantly correlated with a marker of health, stepwise multiple linear regression was subsequently used to further investigate the relationship between the two variables. This regression model adjusted for age and sex



and was built by entering 'age' and 'sex' into the first block of the regression dialog box in SPSS and all 12 FMS into the second block.

For the evaluation of the interventions, only those with pre- *and* post-intervention data for a specific variable were included in the analysis. Paired samples t-tests (when data was normally distributed) and Wilcoxon signed rank tests (when data was not normally distributed) were used to investigate the differences between pre- and post-intervention scores in continuous variables. Repeated measures ANOVAs were used to investigate if there were significant differences in the change in height, FMS, perceived FMS competence and PA variables from pre- to post-intervention between the intervention and control groups. Subsequently, repeated measures ANCOVAs were used to investigate if the change in markers of health (BMI, BMI SDS, SBP, SBP SDS, DBP, DBP SDS, heart rate, WC, WC SDS, 550m time, 550m time SDS) from pre- to post-intervention differed significantly between the intervention and control groups while controlling for the change in height. (A 'change in height' variable was created in SPSS. This was calculated as: post-intervention height minus pre-intervention height. This variable, 'change in height' was then entered into the 'covariates box' of the repeated measures ANCOVA dialog box during the analysis). Effect sizes were calculated as partial eta squared values. Partial eta squared values of 0.0099, 0.0588 and 0.1379 were used as benchmarks for small, medium and large effect sizes, respectively (Cohen, 1969). Cochran's Q was used to investigate pre- to post-intervention differences in the proportion of children who were overweight/obese, centrally obese (i.e. had a WHtR  $\geq$  0.5), had high-normal/high BP, had an above average age and sex-specific 550m time, and for the proportion of children who met the WHO's recommended daily 60 minutes of MVPA every day. Chi-squared tests were used to investigate significant differences between the intervention and control group for these categorical variables at pre- and post-intervention. The significance level was set at  $p < 0.05$  for all statistical tests. All relevant statistical procedures are presented in detail in each respective chapter.

**Chapter 4:**  
**The relationship between fundamental movement  
skills and markers of health among a cohort of  
Irish primary school children**

#### 4.1 Abstract

**Background:** The purpose of this study was to investigate the relationship between fundamental movement skills (FMS) and markers of health among a cohort of Irish primary (elementary) school children. **Methods:** Participants (N=294, mean age:  $7.98 \pm 2.01$  years) were senior infant (n=148, mean age:  $6.02 \pm 0.39$  years) and 4<sup>th</sup> class (n=146, mean age:  $9.96 \pm 0.38$  years) students from 3 primary schools in Cork, a region in southern Ireland. Children's FMS proficiency (Test of Gross Motor Development-2) and markers of health (BMI percentile, WC percentile, BP percentiles, heart rate, CRF and objectively measured PA) measurements were recorded. Correlation and stepwise multiple linear regression analysis were conducted to investigate the relationship between FMS and markers of health. **Results:** A significant, negative relationship was found between FMS (Gross Motor Quotient; GMQ) and 550m time SDS among 6 year olds ( $r=-.286, p<0.01$ ) and 10 year olds ( $r=-.330, p<0.01$ ), indicating that better FMS levels are associated with faster 550m times i.e. higher CRF levels. Significant, positive correlations were found between GMQ and light PA ( $r=.413, p<0.05$ ) and total PA ( $r=.351, p<0.05$ ) among children. Regression analysis revealed that after adjusting for age and sex, FMS explained 15.9% and 20.5% of the variance in 550m time SDS among 6 year olds and 10 year olds, respectively, and 9.7% and 14.4% of the variance in light PA and total PA, respectively. **Conclusion:** The development of a wide range of FMS appears to be important for children's CRF and PA, and should be a focus of attention among children.

**Keywords:** cardiorespiratory fitness, elementary school, gross motor skills, physical activity

## 4.2 Introduction

FMS are basic movement patterns that facilitate participation in sport and PA (Gallahue & Ozmun, 2006). They can be categorised into three subgroups; locomotor, object-control, and stability skills (Lubans et al., 2010). FMS proficiency is positively associated with physiological, psychological and behavioural benefits (Lubans et al., 2010) including fitness (Burns et al., 2017) and PA levels (Logan et al., 2015). Burns et al. (2017) reported a significant negative relationship between locomotor skill proficiency and metabolic syndrome score ( $r=-.21$ ,  $p<0.001$ ) among children (mean age:  $9.1 \pm 1.1$  years), emphasising that further benefits such as a reduced risk of cardio metabolic disease are also associated with FMS proficiency. While these findings suggest that further benefits such as a reduced risk of cardio metabolic disease are also associated with FMS proficiency, it should be noted that the correlation was very small ( $r=-.21$ ). Although a positive association between FMS proficiency and physiological markers of health such as CRF (Barnett, van Beurden, et al., 2008; Marshall & Bouffard, 1997; Okely, Booth, & Patterson, 2001), PA (Capio et al., 2014; Cohen et al., 2014), and adiposity level (Lubans et al., 2010; Slotte et al., 2015), few researchers have examined the relationship between FMS and other physiological markers of health such as heart rate (HR), blood pressure, and PA levels of different intensities (light PA, moderate PA, vigorous PA and MVPA).

In a review article, Lubans et al. (2010) reported a positive relationship between FMS competency and health. However, the majority of the studies included were carried out in Australia and the US, with only three (of 21) studies carried out among European populations. While Lubans et al. (2010), in the review, reported a positive association between FMS and CRF, only one of the four studies that investigated this relationship was carried out among children (aged 5-6 and 9-10 years), and used a process-oriented FMS assessment tool (Marshall & Bouffard, 1997). Marshall and Bouffard (1997) found a moderate, positive correlations ( $r=.48$ ,  $p<0.05$ ) between FMS and CRF among 198 children aged 5-6 and 9-10 years old. Haga (2009) among 9-10 year olds ( $N=18$ ), found that children with low motor competence recorded lower CRF scores than children with high motor competence, suggesting that motor competence is associated with more

favorable CRF. However, the sample size in the study was limited (N=18). Burns et al. (2017) also found a positive relationship (albeit small in size;  $r=.28$ ,  $p<0.01$ ) between FMS and CRF among children (N=224, mean age:  $9.1 \pm 1.1$  years) from low-income elementary schools.

In a review article, Logan et al. (2015) reported a positive relationship between FMS and PA among 6-12 year old children ( $r$  range: .24 to .55,  $R^2=6-30\%$ , 7 studies). It should be noted however, that only one of the 13 studies included was conducted in Europe. Additionally, self-report PA questionnaires were used in the majority of the studies that investigated the relationship among 6-12 year olds. Studies that have investigated the relationship between FMS and objectively-measured PA have produced mixed findings (Barnett, Ridgers, & Salmon, 2015; Cohen et al., 2014; McKenzie et al., 2002). Among children from low-income communities (mean age:  $8.5 \pm 0.6$  years), it was found that no correlation existed between locomotor skill proficiency and daily MVPA ( $r=.150$ ,  $p<0.01$ ) (Cohen et al., 2014). However, object-control competency was positively related to daily MVPA ( $r=.200$ ,  $p<0.01$ ) (Cohen et al., 2014). Similar mixed conclusions were reported by Capio et al. (2014), who found that among 32 Filipino children (mean age:  $6.5 \pm 2.45$  years), FMS proficiency was related to PA during weekend days ( $r=.44$ ,  $p<0.01$ ) but not weekdays ( $r=.16$ ,  $p>0.05$ ). In contrast to research that reported a positive relationship between FMS and PA (Capio et al., 2014; Cohen et al., 2014; Lubans et al., 2010), Cliff et al. (2009) found that among girls, locomotor standard score and GMQ were negatively associated with the percent of time spent in MVPA ( $r=-.50$ ,  $p<0.05$  and  $r=-.46$ ,  $p<0.05$  respectively). In contrast, however, Barnett, Ridgers, and Salmon (2015) found using regression analysis, that among 4-8 year old children (N=102), OC proficiency was not associated with MVPA ( $p>0.05$ ). Furthermore, McKenzie et al. (2002) following stepwise multiple linear regression analysis reported that movement skill competence at the age of 4-6 years did not predict PA level at the age of 12 years ( $p>0.05$ ).

Many researchers have investigated the relationship between FMS and adiposity level among youth (Lubans et al., 2010; O'Brien et al., 2016b; Slotte et al., 2015; Spessato, Gabbard, Robinson, et al., 2013). Slotte et al. (2015) reported that FMS proficiency was negatively related to four measures of adiposity (BMI, WC, body fat percentage and

abdominal fat percentage) among children (albeit, only 5 of the 12 FMS from the Test of Gross Motor Development-2 (TGMD-2) were measured in the study.) Spessato, Gabbard, Robinson, et al. (2013), on the other hand, found no difference in the motor competence of healthy weight, overweight and obese children. Researchers have yet to examine the relationship between FMS and WHtR, which has been found to be a better predictor of adiposity than BMI among children (Brambilla et al., 2013).

It has been projected that Ireland is on track to become the most obese EU nation by 2030 (Webber et al., 2014), specifically comprising of the country's low PA and concerning CRF levels among youth (Woods et al., 2010). With such adverse health predictions, avenues that have the potential to improve the health and well-being of the Irish population is required. One such avenue is the development of FMS proficiency among Irish children (O'Brien et al., 2016a; 2016b). While the relationship that exists between FMS and markers of health among children worldwide is not definitive, some evidence suggests a positive relationship (Lubans et al., 2010). In addition, the relationship between FMS and single health markers such as habitual PA (Cohen et al., 2014), and adiposity level (Cliff et al., 2009; Lubans et al., 2010; Siahkoughian et al., 2011; Slotte et al., 2015) has been examined. To date, researchers have yet to examine the relationship between FMS proficiency, and a comprehensive battery of health markers. The aims of this study were to (i) examine the relationship between FMS proficiency and a range of health markers (CRF, heart rate, BMI, WHtR, BP and PA) among a cohort of Irish primary (elementary) school children and (ii) determine the amount of variance in the markers of health, that can be accounted for as a result of FMS proficiency.

### **4.3 Methods**

Cross-sectional data for the current study were collected as part of a larger longitudinal study evaluating the effectiveness of a child-oriented PA and nutrition intervention entitled Project Spraoi (Coppinger et al., 2016). Project Spraoi is a primary school-based health promotion intervention that aims to increase the PA levels, improve the nutritional habits, and enhance the overall health and well-being of primary school

children. The project is coordinated by a team of researchers from Cork Institute of Technology and works in partnership with Project Energize, New Zealand. Baseline data from Project Spraoi were used for the current study.

Baseline data were collected in October 2014 and 2015 by trained evaluators from the Project Spraoi Research Team. Prior to data collection, consent forms were distributed to 423 children from three primary schools (1 rural mixed-sex; 1 urban single-sex boys; 1 urban single-sex girls) in Cork, a region in southern Ireland. A total of 295 children provided written assent and written parental consent (70%) for their involvement in the study. Only children aged between 3 years and 10 years 11 months were included in the data analysis as the TGMD-2 scoring manual provides age and sex-specific standard scores and GMQ scores for children aged between these ages only. One child from whom data was collected was aged outside of this age bracket and thus this child was not included in the data analysis. Therefore, a total of 294 senior infant (mean age:  $7.98 \pm 2.01$  years) and 146 4<sup>th</sup> class (mean age:  $9.96 \pm 0.38$  years) children were included in the study. Ethical approval was obtained from the Cork Institute of Technology Research Ethics Review Board in September 2014.

### FMS

FMS proficiency was measured using the Test of Gross Motor Development-2 (TGMD-2), a valid and reliable process-oriented FMS assessment tool for 3-10 year olds (Ulrich, 2000). The TGMD-2 consists of 12 skills; 6 locomotor (run, leap, hop, gallop, slide and horizontal jump) and 6 object-control (two-handed catch, overarm throw, underhand roll, kick, two-handed strike and stationary dribble) skills. Data were collected, analysed and raw locomotor subset and object-control subset scores were obtained as described in Chapter 3. Locomotor and object-control subset raw scores were subsequently converted to locomotor standard score (LOCO SS) and object-control standard score (OC SS) respectively, using age- and sex-specific conversion tables in the TGMD-2 manual (Ulrich, 2000). The sum of the subset standard scores were then converted to a gross motor quotient (GMQ) score (range: 46-160) using the conversion table, also in the TGMD-2 manual (Ulrich, 2000).

### Markers of Health

Physical measurements taken were height, mass, WC, heart rate and BP. The protocols used to measure these markers of health are reported in Chapter 3. CRF was measured using a 550m walk/run test (Albon et al., 2010) by following the procedure outlined in Chapter 3.

### PA

PA was measured using tri-axial ActiGraph GT3X accelerometers (Fort Walton Beach, FL, USA) using the protocol described in Chapter 3. A random sample of the children received accelerometers (n=121), due limited accelerometer availability. Of the 121 children who received accelerometers, 70 (57.9%) met the required wear time (at least three weekdays and one weekend day, with a minimum of 10 hours recorded wear time per day (Riddoch et al., 2004). Average daily light PA, moderate PA, vigorous PA, MVPA and total PA (light PA + MVPA ) were calculated.

### Statistical Analysis

Assuming a significance level of 0.05 and power of 0.8, it was determined that a sample of 82 children was needed to detect statistically significant small to moderate correlations ( $r=.30$ ) between the measured variables. To identify if the nature and strength of these relationships differ across childhood, correlations between FMS variables and the physical measurements are presented with children grouped by age i.e. 6 year old and 10 year old groups. However, given the limited sample size from which valid PA data was collected (N=70), children from both age categories were grouped together for the analysis of the PA data. Pearson's product moment correlation and Spearman's rho (when appropriate) were used to investigate the relationship between FMS and markers of health. For 6 year olds, Pearson's product moment correlation was used to examine the relationship between the FMS variables (LOCO SS, OC SS and GMQ) and 550m time SDS and between the FMS variables and resting heart rate. It was also used to examine the relationship between GMQ score and BMI percentile, WC centile, SBP centile and DBP centile. Spearman's rho was used to examine the relationship between the LOCO SS and BMI percentile, WC percentile, SBP percentile and DBP percentile. Spearman's rho was also used to examine the relationship between the OC



SS and BMI percentile, WC percentile, SBP percentile and DBP percentile. For the 10 year old cohort, Pearson's product moment correlation was used to examine the relationship between the FMS variables (LOCO SS, OC SS and GMQ) and 550m time SDS and between GMQ and resting HR, WC percentile, SBP percentile and DBP percentile while Spearman's rho was used to examine the relationship between the FMS variables and BMI percentile. Spearman's rho was also used to examine the relationship between LOCO SS and resting heart rate, WC percentile, SBP percentile and DBP percentile, as well as the relationship between OC SS and resting heart rate, WC percentile, SBP percentile and DBP percentile. Pearson's product moment correlations were used to examine the relationship between all FMS variables and all PA variables. Correlations were classified as non-existent ( $r=0-0.19$ ), small ( $r=0.20-0.39$ ), moderate ( $r=0.40-0.59$ ), moderately high ( $r=0.60-0.79$ ) or high ( $r\geq 0.80$ ) (Zhu, 2012). If correlation analysis revealed a significant relationship between FMS (GMQ score) and a marker of health, stepwise multiple linear regression was used to calculate the proportion of variance in that marker of health that could be explained by each of the individual FMS (after adjusting for age and sex). Significance was set at  $p<0.05$  for all statistical tests.

#### **4.4 Results**

Participants (N=294, mean age:  $7.98 \pm 2.01$  years) were primary school children from senior infants (n=148, mean age:  $6.02 \pm 0.39$  years) and 4<sup>th</sup> class (n=146, mean age:  $9.96 \pm 0.38$  years). Children in senior infants and 4<sup>th</sup> class are subsequently referred to as '6 year olds' and '10 year olds', respectively. Table 4.1 presents descriptive data of the children who participated in the study while Table 4.2 presents the PA results obtained from the subsample of the entire cohort from whom PA was measured (n=76, 46% 6 year olds).

**Table 4.1:** Descriptive data of the children who participated in the study

	6 year olds		10 year olds	
	N	Mean ± SD	N	Mean ± SD
Age (years)	148	6.02 ± 0.39	146	9.96 ± 0.38
Height (cm)	145	115.82 ± 5.35	145	140.60 ± 5.65
Weight (kg)	145	21.57 ± 3.00	145	35.29 ± 6.15
<b>FMS</b>				
Locomotor standard score	144	11.05 ± 2.08	143	8.66 ± 1.96
Object-control standard score	138	8.88 ± 1.80	143	7.35 ± 1.98
Gross motor quotient	138	99.98 ± 8.54	143	88.04 ± 8.86
<b>Markers of health</b>				
550m time standard deviation score	141	0.72 ± 0.72	135	0.40 ± 0.93
Resting heart rate (bpm)	144	87.86 ± 11.71	144	79.55 ± 11.82
BMI percentile	145	57.48 ± 25.74	145	61.21 ± 26.45
Waist circumference percentile	144	48.66 ± 28.90	145	56.03 ± 28.17
Systolic blood pressure percentile	144	39.93 ± 29.90	144	34.73 ± 32.33
Diastolic blood pressure percentile	144	59.84 ± 29.78	144	62.88 ± 26.69

**Table 4.2:** Descriptive statistics (mean ± SD) for the PA data collected from a subsample (n=70, 45.7% 6 year olds) of the children who participated in the study

	Mean ± SD
Light PA (minutes/day)	256.74 ± 42.74
Moderate PA (minutes/day)	36.90 ± 11.09
Vigorous PA (minutes/day)	20.52 ± 13.57
MVPA (minutes/day)	57.42 ± 22.24
Total PA (minutes/day)	314.16 ± 53.07

The relationships between the FMS variables and the collected physical measurements are presented in Tables 4.3 and 4.4. There were statistically significant negative correlations found among the 6 year old cohort between GMQ and 550m time SDS ( $r=-.286$ ,  $p<0.01$ , small effect size), and OC SS and 550m time SDS ( $r=-.324$ ,  $p<0.01$ , small effect size). No statistically significant relationship was observed between OC SS and 550m time SDS among the 6 year old group. Among the 10 year old cohort, there was also a statistically significant negative relationship between GMQ and 550m time SDS ( $r=-.330$ ,  $p<0.01$ , small effect size). However, in contrast to the 6 year old group, there was a statistically significant correlation between LOCO SS and 550m time SDS ( $r=.389$ ,  $p<0.01$ , small effect size), with no statistically significant relationship between OC SS and 550m time SDS. There were no statistically significant correlations between any of

the FMS variables and any other markers of health among either the 6 or 10 year old cohort.

**Table 4.3:** Correlations between FMS variables (locomotor standard score, object-control standard score and gross motor quotient scores) and physical measurements for 6 year olds

	<b>Locomotor Standard Score (n=136-141)</b>	<b>Object-control Standard Score (n=131-136)</b>	<b>Gross Motor Quotient (n=131-136)</b>
550m time standard deviation score	-.098	-.324**	-.286**
Heart rate	-.092	-.063	-.114
BMI percentile	.082	-.133	.132
Waist circumference percentile	.144	-.012	.095
Systolic blood pressure percentile	.105	.006	.063
Diastolic blood pressure percentile	.087	.027	.110

\* $p < 0.05$ , \*\* $p < 0.01$

**Table 4.4:** Correlations between FMS variables (locomotor standard score, object-control standard score and gross motor quotient scores) and physical measurements for 10 year olds

	<b>Locomotor Standard Score (n=134-143)</b>	<b>Object-control Standard Score (n=134-143)</b>	<b>Gross Motor Quotient (n=134-143)</b>
550m time standard deviation score	-.389**	-.112	-.330**
Heart rate	-.191*	.030	-.058
BMI percentile	-.150	-.096	-.152
Waist circumference percentile	-.157	.025	-.083
Systolic blood pressure percentile	.024	-.003	-.010
Diastolic blood pressure percentile	.030	.097	.085

\* $p < 0.05$ , \*\* $p < 0.01$

The relationships between the FMS variables and PA are presented in Table 4.5. A statistically significant positive relationship was found between all three FMS variables and light PA. Small positive correlations were revealed for the relationship between LOCO SS and light PA ( $r = .284$ ,  $p < 0.05$ ), and OC SS and light PA ( $r = .309$ ,  $p < 0.01$ ). A statistically significant moderate correlation was found between GMQ and light PA ( $r = .413$ ,  $p < 0.01$ ). Statistically significant positive correlations were also revealed between all three FMS variables and total PA. These correlations were all small in size ( $r$  range:  $.257$  to  $.351$ ,  $p < 0.05$ ).

**Table 4.5:** Correlations between FMS variables (locomotor standard score, object-control standard score and gross motor quotient scores) and PA

	<b>Locomotor Standard Score (n=70)</b>	<b>Object-control Standard Score (n=67)</b>	<b>Gross Motor Quotient (n=67)</b>
Light PA	.284*	.309*	.413**
Moderate PA	.175	.121	.168
Vigorous PA	.003	-.056	-.054
MVPA	.089	.026	.051
Total PA	.266*	.257*	.351*

\* $p < 0.05$ , \*\* $p < 0.01$ , total PA = light PA + MVPA

As there was a significant negative relationship between GMQ and 550m time SDS among 6, and 10 year olds (This indicates that children with higher FMS levels had faster 550m times than their less skilled counterparts), and significant positive relationships between (i) GMQ and light PA, and (ii) GMQ and total PA (This indicates that children with higher FMS participate in more light and total PA than those less skilled), stepwise multiple linear regression analysis was used to further investigate these relationships. Regression analysis revealed that after adjusting for age and sex, FMS skill scores explained 15.9% and 20.5% of the variance in 550m time SDS among 6 and 10 year olds, respectively (Table 4.6). The full model (including age and sex) for 6 year olds explained 20.2% of the variance in 550m time SDS (Adjusted  $R^2 = 0.202$ ,  $F(4, 125) = 9.140$ ,  $p < 0.01$ ), with the significant predictors being the kick ( $\beta = -.080$ ,  $p < 0.05$ ), dribble ( $\beta = -0.081$ ,  $p < 0.01$ ) and hop ( $\beta = -.097$ ,  $p < 0.01$ ). The model predicts that for each unit increase in kick score, 550m time SDS would decrease by 0.080 units, each unit increase in dribble score would result in a 0.081 unit decrease in 550m time SDS and each unit increase in hop score would result in a decrease of 0.097 units in 550m time SDS. The full model for 10 year olds explained a total of 23.1% of the variance in 550m time SDS (Adjusted  $R^2 = 0.231$ ,  $F(4, 128) = 10.890$ ,  $p < 0.01$ ). Significant predictors in the model were the roll ( $\beta = -0.109$ ,  $p < 0.05$ ), gallop ( $\beta = -.182$ ,  $p < 0.05$ ) and jump ( $\beta = -.226$ ,  $p < 0.01$ ). This model predicts that for each unit increase in roll, gallop and jump scores, there would be 0.109, 0.182 and 0.226 unit decrease in 550m time SDS, respectively.

Regression analysis conducted with light and total PA, respectively as the outcome variables, revealed that after adjusting for age and sex, FMS skills explained 9.7% and 14.4% of the variance in light and total PA, respectively (Tables 4.7). The full model for

light PA explained 33.9% of the variance (Adjusted  $R^2=0.339$ ,  $F(3, 63)=12.285$ ,  $p<0.01$ ). Age ( $\beta=-13.322$ ,  $p<0.01$ ), the roll ( $\beta=7.251$ ,  $p<0.05$ ) and the jump ( $\beta=5.212$ ,  $p<0.05$ ) were identified as significant predictors in the model. The model predicts that for each yearly increase in age, light PA would decrease by 13.32 minutes and for each unit increase in roll and jump score, light PA would increase by 7.25 and 5.21 minutes, respectively. The full model for total PA explained 33.9% of the variance (Adjusted  $R^2=0.339$ ,  $F(5, 61)=7.770$ ,  $p<0.01$ ). Age ( $\beta=-19.443$ ,  $p<0.01$ ), sex ( $\beta=-23.714$ ,  $p<0.05$ ), the jump ( $\beta=8.180$ ,  $p<0.05$ ), the catch ( $\beta=14.415$ ,  $p<0.05$ ) and the strike ( $\beta=-7.603$ ,  $p<0.05$ ) were significant predictors in the model. This model predicts that for each yearly increase in age, total PA would decrease by 19.44 minutes. It predicts that a girl would accumulate 53.71 minutes less total PA than a boy. The model also predicts that for each unit increase in jump and catch score, total PA would increase by 8.18 and 14.42 minutes, respectively, and for each increase in strike score, total PA would decrease by 7.60 minutes.

**Table 4.6:** Stepwise multiple linear regression analysis explaining variance in 550m time SDS for 6 and 10 year olds

	Unstandardised Beta	Standardised Beta	95% Confidence Interval		Adjusted R <sup>2</sup>
			Lower Bound	Upper Bound	
<b>6 year olds</b>					0.202**
Constant	3.175*		1.354	4.996	
Age	-.153	-.082	-.464	.158	
Kick	-.080*	-.207	-.140	-.019	
Dribble	-.081**	-.241	-.137	-.025	
Hop	-.097**	-.266	-.156	-.038	
<b>10 year olds</b>					0.231**
Constant	3.401**		2.358	4.620	
Sex (0=boys)	.333*	.176	.037	.629	
Roll	-.109*	-.207	-.191	-.026	
Gallop	-.182*	-.225	-.305	-.058	
Jump	-.226**	-.376	-.317	-.134	

**Table 4.7:** Stepwise multiple linear regression analysis explaining variance in light and total PA

	Unstandardised Beta	Standardised Beta	95% Confidence Interval		Adjusted R <sup>2</sup>
			Lower Bound	Upper Bound	
<b>Outcome: Light PA</b>					0.339**
Constant	309.027**		267.245	350.808	
Age	-13.322**	-.636	-17.830	-8.814	
Roll	7.251*	.300	2.231	12.272	
Jump	5.212*	.213	.114	10.310	
<b>Outcome: Total PA</b>					0.339**
Constant	432.780**		353.701	511.860	
Age	-19.443**	-.740	-26.683	-12.203	
Sex (0=boys)	-23.714*	-.219	-46.411	-1.018	
Jump	8.180*	.266	1.740	14.621	
Catch	14.415*	.339	2.756	26.075	
Strike	-7.603*	-.229	-14.435	-.770	

\* $p < 0.05$ , \*\* $p < 0.01$

#### 4.5 Discussion

The aim of this study was to investigate the relationship between FMS and markers of health among a cohort of Irish primary school children. Results revealed a significant, negative relationship was found between GMQ and 550m time SDS among both 6 and 10 year old groups, suggesting that those with higher FMS proficiency had faster 550m times and may have higher CRF levels than those less skilled, or vice versa. These findings support those from a study by Burns et al. (2017) in which a significant relationship ( $r=.28$ ,  $p < 0.01$ ) between total FMS score (measured using the TGMD-3) and CRF (when measured using the PACER) was reported among a cohort of primary school aged children from low-income communities. This study by Burns et al. (2017) was carried out among a sample of third to fifth grade children ( $N=224$ , mean age:  $9.1 \pm 1.1$  year) who were of a similar age to that of the 10 year old cohort in the current study (mean age:  $9.9 \pm 0.40$  years). Results of the current study, similar to Burns et al. (2017), found a small, significant, positive relationship between locomotor skills and CRF ( $r=.34$ ,  $p < 0.01$ ) and no significant relationship between object-control skills and CRF ( $r=-.113$ ,  $p > 0.05$ ). Marshall and Bouffard (1997) also reported similar findings with a significant small positive correlation reported between LOCO and CRF ( $r=.32$ ,  $p < 0.05$ ), and no significant relationship found between OC and CRF ( $r=.18$ ,  $p > 0.05$ ) among 9-10 year old children. Marshall and Bouffard (1997), similar to the current study, also examined the

relationship between FMS and CRF among a younger cohort (aged 5-6 years). The findings reported among the 5-6 year old cohort were similar to those of the current study for OC and CRF ( $r=.25, p<0.05$ ), and total FMS score and CRF ( $r=.35, p<0.05$ ), with small positive relationships found. However, in contrast to the current study, Marshall and Bouffard (1997) also reported a significant correlations between LOCO and CRF among 5-6 year old children.

The statistically significant relationship between FMS and 550m time SDS is very encouraging given that CRF is a very important marker of health, so much so that Ruiz, Ortega, et al. (2006) suggests that it should become part of all health screening assessments. It is interesting to note that the relationship between FMS and CRF was largely due to the OC proficiency among 6 year olds and largely due to LOCO proficiency among 10 year olds. It is likely that the significant correlation between GMQ and CRF is due to a greater engagement in PA (possibly organised sport) by those who have higher levels of FMS proficiency. Children who participate in organized sport not only have higher CRF than those who do not (Drenowatz et al., 2013), they also have the opportunity to receive appropriate instruction and feedback from coaches for FMS. The significance of the correlation specifically between OC and CRF found among 6 year olds may be an indication as to the types of sports/physical activities that these more active children participate in. With Gaelic games (football and hurling), soccer and basketball popular recreational activities (Woods et al. 2010), children who had higher CRF are likely to have engaged in these types of OC based activities and as a result develop a basic level of proficiency compared to their less active counterparts who may have had a very limited level of OC proficiency. The lack of significance between OC and CRF among 10 year olds is surprising given the popularity of these OC based sports among this age group also. However, given the predominance of soccer, basketball and football in primary school PE classes (Woods et al., 2010), perhaps the majority of children have developed a basic level of OC proficiency by this age (irrespective of any activity outside of PE that may account for differences in CRF). A possible explanation for the significant relationship between LOCO and CRF among 10 year olds may be that children who are more efficient in their movement from one place to another (i.e. demonstrate superior proficiency in locomotor skills) participate in greater amounts of organised sport than

their less efficient counterparts. Furthermore, within sporting settings, children who demonstrate greater movement capabilities (i.e. have greater LOCO skills) may be selected to play in central positions on sporting teams and so those with higher LOCO may have the opportunity to enhance their CRF. A possible explanation for the insignificant relationship between LOCO and CRF among 6 year olds may be that the difference in children's movement capabilities may not have been as apparent to coaches when selecting teams or positions for children at 6 years as they are typically smaller and move much slower than 10 year olds and thus differentiating between the children based on speed or efficiency for position selection may not have occurred. Perhaps children are assigned positions based on OC proficiency at this age.

The current study found that FMS explained 15.9 and 20.5% of the variance in 550m time SDS among 6 and 10 year olds, respectively (after adjusting for age and sex). A larger amount of the variance in 550m time was explained among the 10 year old groups (when compared to the younger groups), suggesting that FMS proficiency may be even more important for CRF as children get older. Okely et al. (2001) also found that FMS could predict CRF among youth, with FMS explaining 12-26% of the variance among adolescents. These lower values reported by Okely et al. (2001) may be explained by the different CRF (Multistage Fitness Test) and FMS assessment tools used in that study. While FMS development appears to be important for CRF among children (current study) and adolescents (Okely et al., 2001), Barnett, van Beurden, et al. (2008), in a longitudinal study, reported that childhood FMS proficiency accounted for 26% of adolescent fitness, highlighting that FMS proficiency may not only be important for current CRF but also future CRF.

The kick, dribble and hop were identified as significant predictors of 550m time SDS among for the 6 year old cohort, suggesting that these skills are important for CRF among children of this age. Similarly, the roll, gallop and horizontal jump were significant predictors of 550m time SDS among the 10 year old group, suggesting that these skills are of utmost importance for CRF among this group. There was no particular skill that featured in both prediction models (i.e. the models for 6 and 10 year olds), indicating that a range of skills is important for CRF.



Given that CRF was tested using the time taken to run/walk 550m, it was surprising that the run was not a significant predictor of 550m time for any group. However, it has been suggested that the run may not relate to CRF using a process-oriented assessment tool, because it is the technique of the movement that is evaluated using such tools, as opposed to the outcome (i.e. speed or endurance) (Barnett, van Beurden, et al., 2008). While the current study suggests that certain skills may be more important than others (i.e. are significant predictors) for CRF among children, the development of a wide array of FMS is recommended to allow for participation in a wide range of activities. The negative relationship between FMS and 550m time SDS may be explained by the possibility that children with higher FMS proficiency take part in more PA, as higher PA levels in children are associated with improved CRF (Morrow et al., 2013). The positive relationship found between FMS and PA in the current study provides support for this explanation. Given that regression analysis revealed that FMS explained 14.4% of the variance in total PA (after adjusting for age and sex), the development of FMS may have the potential to enhance PA levels among children. Although there was no statistically significant correlation between FMS and MVPA, correlations between light PA and total PA were found which suggests that those more competent at FMS engage in more PA than those who do not. It should be noted however that the size of the correlations were small to moderate in size. Given the sedentary nature of children (that has come as a result of enhanced technology such as the emergence of iPods, tablets and video games) any increase in PA may bring about health benefits (even though it may not be MVPA.)

Surprisingly, an increase in strike score predicted a decrease in total PA. A possible explanation for this may be because the required skill components of the strike (as outlined by the TGMD-2) are different to those that would typically be used in traditional Irish games (hurling and camogie). The TGMD-2 requires the dominant hand to be positioned above the non-dominant hand on the bat during the performance of the strike i.e. the grip that would typically be used in baseball, cricket or hockey. However, this grip is the opposite to what is typically used in hurling/camogie, (Players typically grip the hurl (stick) with the non-dominant hand on top of the dominant hand when playing these games).

Correlation analysis revealed that there was no significant relationship between either FMS and WC percentile or FMS and BMI percentile ( $p>0.05$ ). To date, mixed findings for the relationship between FMS and BMI have been reported (Siahkoughian et al., 2011; Slotte et al., 2015; Spessato, Gabbard, Robinson, et al., 2013). When a negative correlation between FMS and BMI is found, it appears to be largely due to the negative relationship between locomotor skills and BMI, rather than the relationship between object-control skills and BMI. For instance, Siakhouhian et al. (2011) found a significant negative relationship between BMI and three out of four locomotor skills tested ( $p<0.05$ ) but with none of the four object-control skills tested ( $p>0.05$ ). Among an Irish cohort, albeit adolescents, O'Brien et al. (2016a) found significant, negative correlations between LOCO and BMI among both boys and girls ( $r=-.367$  and  $r=-.341$  respectively,  $p<0.05$ ), but no significant relationship between OC and BMI among either boys or girls ( $p>0.05$ ). It has been suggested that the negative relationship between LOCO and BMI may be due to overweight/obese children having larger overall body masses, making it more difficult for them to move from one place to another when compared to their leaner peers (O'Brien et al., 2016b). However, as the TGMD-2 is a process-oriented assessment tool which evaluates qualitative aspects of movement over a short period of the time, the performance scores are independent of physical fitness (cardiorespiratory and muscular endurance) and physical characteristics (mass and height) (Kim & Lee, 2017). Differences in FMS proficiency may therefore be due to other factors such as the quality and amount of instruction, feedback and practice experience, which are necessary for the development of FMS (Gallahue et al., 2012; Logan et al., 2011; Morgan et al., 2013).

Based on the TGMD-2's GMQ classification (<70=very poor, 70-79=poor, 80-89=below average, 90-110=average, 111-120=above average, 121-130=superior, >130=very superior) results of the current study revealed that the 6 year old cohort demonstrated 'average' FMS proficiency when compared to the normative data presented in the TGMD-2 manual (Ulrich, 2000). However, the 10 year old cohort demonstrated 'below average' FMS levels. These below average FMS levels may be due to a number of reasons. Firstly, primary school PE is a legal requirement in 89% of countries worldwide (Hardman, 2008). However, Ireland is not one of these countries. In Ireland, the Irish

Department of Education and Skills merely 'recommend' that Irish children engage in 60 minutes of PE every week. This is the lowest level of PE of all EU nations (European Commission/EACEA/Eurydice, 2013). Despite these low targets, Woods et al. (2010) reported that only 35% of primary school children actually receive this recommended 60 minutes of PE per week. Furthermore, primary school PE in Ireland is taught by the classroom teacher who Morgan and Hansen (2008) have previously outlined lack confidence and competence in delivering PE to their students. With low FMS proficiency reported among Irish primary school children (Bolger et al., 2017; Farmer et al., 2017), the quantity and quality of PE delivered to Irish primary school children warrants attention. The Irish primary school PE curriculum is designed to target 6 strands of activities (games, athletics, outdoor adventure, dance, aquatics and gymnastics). Despite six strands/groups of activities identified, Woods et al. (2010) reported that the content of Irish primary school PE classes is largely dominated by team sports (an aspect of the games strand), with relatively large proportions of children reporting no engagement in activities from the other five strands during PE during their previous year in school. (A total of 42% of children reported that they did not participate in athletics while 50%, 57%, 70% and 89% reported not participating in aquatics, dance, gymnastics and outdoor adventure, respectively). Low FMS proficiency levels have been reported among Irish primary school children (Bolger et al 2017; Farmer et al., 2017), suggesting that Irish primary school children are instructed to engage in physical activities despite possessing the necessary fundamental skills to do so competently. Thus, the development of FMS should be the primary aim/focus of the Irish primary school curriculum so that children can competently engage in the activities referred to in the various strands of the Irish primary school curriculum.

It should be emphasised that FMS do not occur naturally but require appropriate instruction, feedback and practice (Logan et al., 2011; Morgan et al., 2013; Stodden et al., 2008). This highlights the need for an increase in teacher training in the area of FMS development and PE so that teachers can design appropriate activities and provide appropriate instruction and feedback to their students. A greater provision of time for PE in the curriculum is required to allow for practice and opportunities to receive appropriate feedback. In addition, PE which is currently 'recommended' to be carried

out for a minimum of 60 minutes per week, should be made compulsory as it is often omitted from teachers' weekly lessons due to the overcrowded curriculum and the emphasis on producing students to achieve high standardised test scores in academic subjects such as English and maths.

### Strengths and Limitations

A strength of the study is the use of a comprehensive battery of health markers. Other strengths are the use of an objective measure of PA, and a relatively large sample size from which FMS and physical measurements were collected. A limitation is the small sample from which PA data was attained. Among the group of children who received accelerometers (n=121), the rate of accelerometer wear-time compliance was 63%, meaning that PA data from only 26% of the total sample (76 of 298 children) was used in the analysis. Future researchers who intend to collect of PA data should consider the use of wrist-worn accelerometers which are valid (Ekblom, Nyberg, Bak, Ekelund, & Marcus, 2012; Hislop, Palmer, Anand, & Aldin, 2016) and reliable (Ekblom et al., 2012; Ozemek, Kirschner, Wilkerson, Byun, & Kaminsky, 2014) measures of PA, as compliance rates have been found to be superior for these than hip-worn devices (Fairclough et al., 2016).

While accelerometers are an objective measure of PA, they cannot be worn in water, and are insensitive to non-ambulatory activities (e.g. cycling) and so may underestimate the amount of PA undertaken. To obtain a more accurate measurement of children's PA levels, PA diaries in conjunction with accelerometers should be considered. Furthermore, anecdotally some children reported removing their accelerometers before going to play sport despite being instructed to wear at all times except sleeping and in aquatic activities and so PA diaries may capture these activities undertaken during 'non-wear' times.

A further limitation relating to the measurement of PA that should be noted was that although PA data were collected in 15-second epochs, the data were analysed in 60-second epochs (i.e. the data were scaled up by a multiple of 4 to their 60-second equivalents and the 60-second equivalents of Evenson et al.'s (2008) cut-points were

subsequently applied). This scaling up may have resulted in the misclassification of PA data and thus should be recognised as a limitation.

While relationships between FMS and markers of health were identified, the cross-sectional design of the study does not allow the direction of the relationships to be inferred i.e. whether the development of FMS promotes enhanced health, or whether better health status allows for enhanced FMS proficiency. While Barnett et al. (2011) reported a reciprocal relationship between object-control proficiency and MVPA, and a one-way relationship from MVPA to locomotor proficiency among adolescents, no such investigations have been carried out among children. Future research should carry out investigations to determine the direction of the relationship between FMS and a comprehensive battery of markers of health among children.

While the analysis of the current study was carried out with children subdivided based on their age (i.e. 6 year olds and 10 year old groups), future researchers should consider investigating the relationships between FMS and markers of health with children stratified by both age and sex as had been carried out by Okely et al. (2001) among an adolescent cohort.

Furthermore, researchers in future should consider using a larger sample than was used in the current study so that the relationship between FMS and markers of health can be analysed accurately when subdivided based on age and sex. While the current research collected data from only two class cohorts, future researchers should consider collecting data from children across the full range of primary school class groups i.e. from junior infants to 6<sup>th</sup> class (5 years to 12 years.) to gain a greater insight into the nature of the relationships between FMS and the markers of health, and also if these relationships change as children age.

#### **4.6 Conclusion**

FMS proficiency was negatively related to 550m time SDS (indicating that higher FMS proficiency is associated with faster 550m times i.e. better CRF) and positively related

to PA among Irish primary school children, suggesting that FMS should be developed during the primary school years (4-13 years) to promote CRF and PA. There was no significant relationship identified between FMS and the other markers of health (heart rate, WC percentile, BMI percentile and BP percentiles) among 6- or 10-year old Irish children. While further investigation into these relationships among children is warranted, it is recommended that children develop a wide range of FMS to allow for participation in a wide variety of physical activities and sport, and thus healthy, active lifestyles.

**Chapter 5:**  
**The effectiveness of a physical activity  
intervention on the fundamental movement skill  
proficiency and markers of health among a cohort  
of Irish primary school children**

## 5.1 Abstract

**Background:** PA is associated with positive health outcomes among children. Despite this, less than one in five Irish primary school children engage in the recommended daily 60 minutes of MVPA. School-based interventions have been found to be effective for improving PA, fitness and reducing overweight/obesity among children. Project Spraoi is a PA- and nutrition-based intervention that aims to improve the PA and healthy eating habits of Irish primary school children. The purpose of this study was to evaluate the effectiveness of a PA intervention on FMS and markers of health among a cohort of Irish primary school children. **Methods:** Children (N=217) from the senior infant (6 year olds) and 4<sup>th</sup> classes (10 year olds) of 3 primary schools in Co. Cork, a southern region of Ireland participated in the study. FMS proficiency (Test of Gross Motor Development-2; Ulrich, 2000), BMI, WHtR, BP, HR, CRF (550m walk/run) and objectively measured PA (via accelerometry) were measured at baseline and following the 6-month intervention. **Results:** Results revealed that there were significant positive intervention effects for WC SDS among 6 ( $p<0.01$ ,  $\eta_p^2=0.298$ , large effect size) and 10 year olds ( $p<0.01$ ,  $\eta_p^2=0.061$ , medium effect size). There were also significant positive intervention effects for WC ( $p<0.01$ ,  $\eta_p^2=0.280$ , large effect size) and WHtR ( $p<0.01$ ,  $\eta_p^2=0.288$ , large effect size) among 6 year olds, and 550m time SDS ( $p<0.01$ ,  $\eta_p^2=0.115$ , medium effect size) among 10 year olds. There was a significant increase in the proportion of children achieving above average 550m times among the 10 year old intervention group following the intervention ( $p<0.05$ ). There were no significant intervention effects for any of the FMS based variables ( $p>0.05$ ). **Conclusion:** A school-based PA-based intervention positively affected children's levels of central adiposity. Adaptations to the intervention are necessary to elicit improvements in FMS proficiency and further health benefits.

**Keywords:** physical activity, cardiorespiratory fitness, motor skills, elementary school



## 5.2. Introduction

Compared to recommended levels, standardised normative values and international counterparts, levels of PA (Bel-Serrat et al., 2017; Woods et al., 2010), CRF (Hudson et al., 2015; Woods et al., 2010) and FMS (Bolger et al., 2017) reported among Irish youth are low. It has been reported that only 19% of Irish primary school children and 12% of post-primary school children engage in the recommended daily 60 minutes of MVPA while one in four children were found to be unfit, overweight or obese and had high BP (Woods et al., 2010). Furthermore, despite children having the potential to master FMS by the age of 6 (Gallahue & Ozmun, 2006), a study among Irish primary school children revealed that no child could demonstrate mastery in all 12 FMS assessed (Bolger et al., 2017). In fact, the study which was carried out among 6 and 10 year old children, found that no 6 year old child demonstrated mastery in more than 6 FMS, while no 10 year old child demonstrated mastery in more than 10 FMS (Only one 10 year old child achieved mastery in 10 FMS). These findings in addition to reports that outline that Ireland is on track to become the fattest of 53 EU nations by 2030 (Webber et al., 2014) highlight the need for interventions to improve the health and well-being of Irish youth.

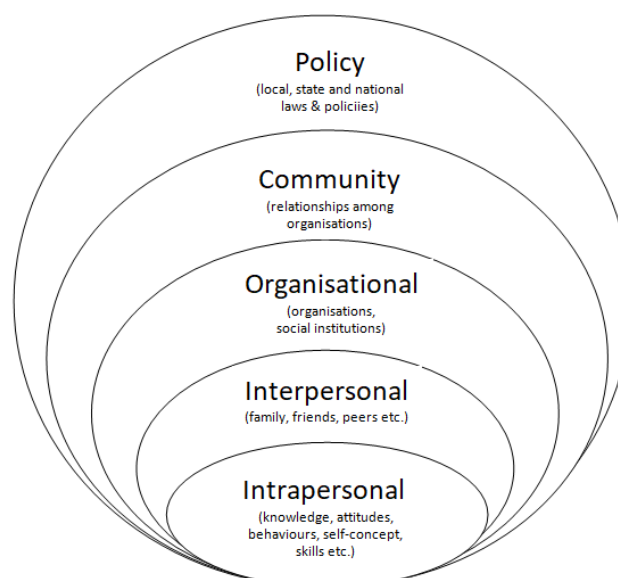
Schools have been identified as key settings for health-promotion interventions (Centers for Disease Control and Prevention, 2011) because of the large quantity of children (including those at risk of being physically inactive) that can be reached and the wide range of resources available (e.g. qualified teachers, sports halls, sports equipment, scheduled PA time) (Cohen, Morgan, Plotnikoff, Callister, et al., 2015). With PA, CRF and overweight/obesity tracking from childhood to later life (Herman et al., 2009; Telama et al., 2014; Twisk et al., 2000), the early years of life i.e. the primary school years, appear to be a key time for intervention. According to Gallahue and Ozmun (2006) the early childhood years (approximately ages 3-7 years) are a critical period for the development of proficiency in FMS, which has been found to support continued participation in sport and PA.

Currently, there is a dearth of research which has evaluated the effect of PA interventions among Irish primary school children. Two interventions that have been

evaluated were the Bizzy Break! (Murtagh et al., 2013) and Active Classroom (Martin & Murtagh, 2015) interventions. The findings from these studies suggest that school-based PA interventions among Irish primary school children may be effective at promoting PA. The Bizzy Break! intervention consisted of one 10-minute PA break every day (Murtagh et al., 2013). Results of the study revealed that although both intervention and control groups accumulated significantly less steps at the end of the intervention period (Intervention: -297 steps/day, Control: -1222 steps/day,  $p < 0.05$ ), there was a significantly greater decrease in steps accumulated among the control relative to the intervention group ( $p < 0.05$ ). The Active Classroom intervention of Martin and Murtagh (2015) that consisted of the delivery of one active maths and one active English lesson per day, reported that children spent 70% of the duration of an active lesson engaged in PA compared to only 0.9% of the duration of a regular lesson engaged in PA. While the study also involved the measurement of MVPA across the whole school day (school-day MVPA), it did not involve the measurement of school-day MVPA during a week without the intervention and so it remains inconclusive as to whether such active lessons resulted in higher school-day PA. However, the study did report that children accumulated a mean of 24.8 minutes of school-day MVPA per day during the intervention which is higher than the 18.6 minutes of school-day MVPA that was reported by Murtagh et al. (2013) in an evaluation of Irish primary school children's PA levels during a segmented school day. These findings suggest that the delivery of active lessons may have the potential to increase children's PA levels during the school day. Both the Bizzy Break! and Active Classroom interventions were very short in duration (5 days) and so an investigation of the sustainability of such interventions is warranted. Furthermore, these interventions were evaluated using small sample sizes (ranging from 20 to 90 participants).

In comparison to these short duration interventions, Project Energize (New Zealand) has delivered whole-school primary school-based PA interventions for a sustained period of time (>10 years) (Rush et al., 2016). Evaluations carried out on Project Energize interventions have produced positive results for BP, adiposity (Rush et al., 2012), CRF (Rush et al., 2014) and FMS (Mitchell et al., 2013) among children. Project Spraoi, an adapted version of Project Energize has been delivered to over 10 schools in Co. Cork,

Ireland since its origin in 2013. While baseline (pre-intervention) findings from research carried out by the Project Spraoi Research Team has been reported (Bolger et al., 2017; Coppinger et al., 2016), results of the effectiveness of the Project Spraoi interventions have yet to be published. A strength of Project Spraoi is its basis upon the socio-ecological model of health (SEM) (Figure 5.1) (McLeroy et al., 1988). The SEM outlines that behaviour is determined by a number of factors including intrapersonal factors, interpersonal factors, institutional factors, community factors and public policy. Project Energize and Project Spraoi attempt to target these different factors in order to bring about a change in children’s behaviours i.e. increase their PA levels and improve their eating habits. Project Spraoi attempts to address each of these factors (Table 5.1).



**Figure 5.1:** The socio-ecological model for health (McLeroy et al., 1988)

**Table 5.1:** Project Spraoi and the socio-ecological model for health

<b>Factor</b>	<b>How Project Spraoi aims to target this factor of the SEM</b>
Intrapersonal	<ul style="list-style-type: none"> <li>• Increase actual and perceived FMS competence</li> <li>• Increase PA levels</li> <li>• Increase knowledge and awareness of the importance of PA and healthy eating</li> </ul>
Interpersonal	<ul style="list-style-type: none"> <li>• Educate parents and families in the areas of FMS and the importance of PA and healthy eating</li> </ul>
Institutional	<ul style="list-style-type: none"> <li>• Promote PA and healthy eating at school</li> <li>• Deliver quality PA and FMS sessions in school</li> </ul>
Community	<ul style="list-style-type: none"> <li>• Linking with local sports clubs and universities for the use of resources</li> </ul>
Public Policy	<ul style="list-style-type: none"> <li>• Evaluating the Project and presenting results to local authorities in an attempt to provide funding or make such a programme mandatory in school</li> </ul>

Research has outlined that multicomponent interventions that involve school- and home-based components appear to be effective in increasing overall PA (Kriemler et al., 2011) and FMS (Tompsett et al., 2017) among children. Key school-based components include the delivery of PA sessions by PE specialists (Kriemler et al., 2011) and the inclusion of activity breaks throughout the school day (Salmon et al., 2007). Key home-based components identified were at-home practice and family support/involvement (Tompsett et al., 2017). Furthermore, interventions longer than 6 months that provide multiple learning opportunities per week (with PE specialists) are associated with enhanced FMS proficiency (Tompsett et al., 2017). The inclusion of these key components of effective interventions add to the strengths of Project Spraoi.

Given the low PA, CRF and FMS levels of Irish children and the dearth of literature relating to the effectiveness of PA interventions, the aim of the current study was to evaluate the effectiveness of a PA intervention on markers of health (BMI, BMI SDS, WC, WC SDS, WHtR, SBP, SBP SDS, DBP, DBP SDS, CRF and PA level) and FMS proficiency (locomotor, object-control and overall FMS) among a cohort of Irish primary school children.

### **5.3 Methods**

#### Study Design and Participants

Ethical approval for the current research was granted by Cork Institute of Technology Research Ethics Review Board in September 2014. Children from three primary schools in Cork, a region in southern Ireland were invited to participate in the study. The school selection process has been previously outlined elsewhere (Coppinger et al., 2016). In brief, schools were required to be of a medium size (100-300 students), have their location within 20km of the research institute, be willing to implement the intervention and not be involved in any other PA and/or healthy eating intervention during the time of the intervention. Children from two intervention (1 urban single-sex boys and 1 urban single-sex girls) schools and one control (rural mixed sex) school participated in the study. While the intervention was delivered to the whole school, only the children in the

senior infant and 4<sup>th</sup> classes were invited to participate in the evaluation. These class groups were chosen on the basis that they mostly include the age groups of 6 and 10 year olds which mark sensitive periods of growth for children (mid-childhood and early adolescence) (Cameron & Demerath, 2002) and also to allow for follow up after 2 school years. An information sheet and a consent form (Appendix E.3) were distributed to all 298 children in the senior infant or 4<sup>th</sup> classes of the participating schools. A total of 217 provided written assent and parental consent to participate (72.8% consent rate). Baseline/pre-intervention data were collected in October 2015 and post-intervention data were collected in April 2016. All data were collected by a members of the Project Spraoi Research Team who were researchers qualified in the area of exercise and health. Outcomes measured were FMS proficiency, physical measurements, CRF and PA.

### FMS

A total of 6 locomotor (run, leap, hop, gallop, slide and horizontal jump) and 6 object-control (catch, overhand throw, underhand roll, two-handed strike, kick, stationary dribble) skills were assessed using the Test of Gross Motor Development-2 (TGMD-2), a valid and reliable assessment tool for 3-10 year olds (Ulrich, 2000). The FMS testing protocol described in Chapter 3 was used to collect and analyse the FMS data. Locomotor (LOCO) and object-control subset scores (OC) were calculated and then summed to give an overall FMS score (TOTAL FMS: range 0-96) (Ulrich, 2000).

### Physical Measurements

Physical measurements taken were height, mass, WC, heart rate and BP. The measurements were collected using the procedures outlined in Chapter 3.

The Excel add-in LMS-growth programme (version 2.77) was used to calculate standard deviation scores from the British 1990 child growth reference data for age- and sex-specific SDS of BMI (Cole et al., 1995) and SBP and DBP (Jackson et al., 2007).

The age- and sex-specific International Obesity Task Force (IOTF) cut-points for BMI were used to categorise children as either 'non-overweight' or 'overweight/obese' (Cole et al., 2000). The age- and sex-specific BP centiles of Jackson et al. (2007) were used to

classify children as either having 'normal' ( $\leq 91^{\text{st}}$  centile) or 'high-normal/high' BP ( $> 91^{\text{st}}$  centile). Children were classified into one of two WHtR categories based on the universally accepted 0.5 cut-off value (Yoo, 2016), with those with a WHtR of less than 0.5 deemed 'not centrally obese' and those with a WHtR of 0.5 or above as 'centrally obese'.

#### CRF

CRF was measured using the 550m run/walk test (Albon et al., 2010), which has been found to be a valid measure of CRF among children (Hamlin et al., 2014). This test was conducted as outlined in Chapter 3. Time taken to complete the 550m was converted from minutes and seconds, into total seconds. Age and sex-specific 550m run SDS were calculated using the run centile curves developed by 'Project Energize' evaluation data (Rush & Obolonkin, 2014). These centile curves were also used to categorise children into one of two categories; above average ( $\geq 50^{\text{th}}$  centile) or below average ( $< 50^{\text{th}}$  centile).

#### PA

Due to limited accelerometer availability, a random sample of children was selected to wear tri-axial ActiGraph GT3X accelerometers (Fort Walton Beach, FL, USA) for 7 consecutive days. PA data was collected and analysed as outlined in Chapter 3. Evenson et al. (2008) cut-points were used to identify the quantity of time spent in light PA, moderate PA, vigorous PA, MVPA and total PA as these cut-points have been shown to be valid for children aged 5-15 years (Troost et al., 2011). Mean MVPA and mean weekend day MVPA were also calculated. Based on the WHO's recommendation that children should engage in at least 60 minutes MVPA daily, children's' mean weekday, weekend and daily MVPA levels were used to categorise them as either 'sufficiently active' (mean MVPA  $\geq 60$  minutes) or 'not sufficiently active' (mean MVPA  $< 60$  minutes).

In October 2014, 48 randomly selected children (intervention  $n=32$ ; control  $n = 16$ ) (22%) received accelerometers. To promote wear time compliance, the researcher distributed accelerometer information sheets (Appendix E.4) to children to bring home as the accelerometers were distributed. Furthermore, SMS messages were sent to the parents/guardians of those children who received accelerometers each morning during

the PA data collection period (i.e. on the days when the child had the accelerometer) (Belton, O'Brien, Wickel, & Issartel, 2013). Only children who met the wear time criteria of a minimum of 10 hours on three weekdays and one weekend day at both pre- and post-intervention were included in the analysis. A total of 17 children (6 senior infant and 11 4<sup>th</sup> class students; 35.4% of those who received accelerometers at pre-intervention; 7.8% of the total sample) provided valid accelerometer data i.e. met the minimum wear time requirements, at both pre- and post-intervention, and were included in the analysis.

### Intervention

The PA intervention was delivered as part of Project Spraoi, a primary school-based PA and nutrition intervention. The intervention was implemented across 6 months, from November 2014 to April 2015, in two intervention schools (one urban single-sex boys and one urban single-sex girls). The intervention was delivered to each of these schools by an Energizer (a qualified sport scientist with extensive experience in delivering PA sessions to primary school-aged children).

A detailed account of the intervention is provided in Chapter 3. In summary, Energizers delivered 2 x 25 minute 'huff and puff' (high-intensity) sessions to each class each week. They also encouraged and provided support for teachers to enable them to deliver opportunities for children to engage in at least 20 minutes of MVPA during class time on the remaining school days. A whole school PA initiative, namely the 'Stride for 5' was introduced to further promote children's engagement in PA and posters and laminated cards promoting PA and healthy eating were distributed to schools and families. Intervention schools also received 2 x 25 minute nutrition lessons during the intervention, one based on sugary drinks and the other on the major food groups of the food pyramid.

The control schools were instructed to follow their PE programme. According to the Department of Education and Skills, it is recommended that primary schools engage in at least one hour of physical education per week (Department of Education and Science, 1999).

### Process Evaluation

Process evaluation was carried out on the 9<sup>th</sup> February 2015 as outlined in Chapter 3. In summary, data was collected during a meeting with teachers. Teachers were divided into small groups and were asked to answer questions relating to the positive aspects of the interventions to date, barriers to delivering 20 minutes PA every day with their classes and ways in which the Energizer could assist them (the teachers) to achieve 20 minutes PA daily with their classes. The answers to the questions and potential improvements to the intervention were subsequently discussed among the group as whole.

### Statistical Analysis

Data were analysed using SPSS version 22. Only children who had both pre- and post-intervention data (for each of the measured variables) were included in the analysis. Assuming a significance level of 0.05 and power of 0.8, it was determined that a sample of 34 children was needed to detect statistically significant medium effect size. For the purpose of this research, the senior infant and 4<sup>th</sup> class cohorts are subsequently referred to as 6 and 10 year olds, respectively. Data (except PA data) were analysed with children grouped by age i.e. 6 year old and 10 year old groups. Due to the limited sample size from which valid PA data was collected, children from both age categories were grouped together for the analysis of this data. Means, standard deviations and frequencies are used to summarise the data. Data were assessed for normality. When data was normally distributed, paired samples t-tests were used to investigate differences in variables over time (i.e. between pre- and post-intervention). Paired samples t-tests were used to examine the pre- to post-intervention change in the 6 year old intervention group's height, SBP, HR, 550m time SDS and total FMS scores, the 6 year old control group's height, BMI SDS, DBP SDS, HR, WC, WC SDS, WHtR, 550m time, 550m time SDS, LOCO and OC scores, the 10 year old intervention group's height, BMI SDS, SBP SDS, DBP SDS, WC, SDS and OC scores, and the 10 year old control group's height, BMI SDS, 550m time and OC scores. When data were not normally distributed, Wilcoxon signed rank tests were conducted. Wilcoxon signed ranks tests were used to examine the pre- to post-intervention change in the 6 year old intervention group's mass, BMI, BMI SDS, SBP SDS, DBP SDS, DBP, WC, WC SDS, WHtR, 550m time, LOCO and OC scores, the 6 year old control group's mass, BMI, SBP SDS, SBP, DBP and total FMS



scores, the 10 year old group’s mass, BMI, SBP, DBP, HR, WC, WHtR, 550m time, 550m time SDS, LOCO and total FMS scores, and the 10 year old control group’s mass, BMI, SBP SDS, DBP SDS, SBP, DBP, HR, WC, WC SDS, WHtR, 550m time SDS, LOCO and total FMS scores. Repeated measures ANOVAs were run to investigate if there were any differences from pre- to post-intervention with respect to group (i.e. intervention and control) for height, FMS, and PA i.e. to assess if there were significant differences in the change in these variables from pre- to post-intervention between the intervention and control groups. If there was a significant group by time interaction effect for height i.e. if one group grew significantly taller than the other group from pre- to post-intervention, repeated measures ANCOVAs were carried out to examine the effectiveness of the intervention on the remaining measured markers of health while controlling for the change in height. When the repeated measures ANOVA or ANCOVA revealed a group by time interaction i.e. when the difference between the intervention and control groups from pre- to post-intervention was significant, partial eta squared values were used to determine the size of effect (Cohen, 1969) (Table 5.2).

**Table 5.2:** Effect size classification (Cohen, 1969)

<b>Effect size classification</b>	<b>Partial eta squared</b>
Negligible effect size	<0.0099
Small effect size	0.0099 < partial eta squared < 0.0588
Medium effect size	0.0588 < partial eta squared < 0.1379
Large effect size	≥0.1379

Chi-squared tests were used to investigate if there were significant differences in the proportion of children who were overweight/obese, centrally obese (i.e. had a WHtR ≥ 0.5), had high-normal/high BP, had an above average age and sex-specific 550m time, and for the proportion of children who met the WHO’s recommended daily 60 minutes of MVPA every day, between the intervention and control groups. Cochran’s Q tests were used to identify any significant pre- to post-intervention differences in these measures among the intervention and control groups.

## 5.4 Results

A total of 107 senior infant (mean age:  $6.00 \pm 0.40$  years) and 110 4<sup>th</sup> class (mean age:  $9.91 \pm 0.40$  years) children participated in the study. Information relating to the children who participated in the study is presented in Table 5.3.

**Table 5.3:** Sex, age and group information of children who participated in the study

	6 year olds (n=107)			10 year olds (n=110)		
	Boys (n)	Girls (n)	Age (Mean $\pm$ SD)	Boys (n)	Girls (n)	Age (Mean $\pm$ SD)
Intervention (n=111)	30	24	$5.87 \pm 0.42$	29	28	$9.87 \pm 0.43$
Control (n=106)	26	27	$6.13 \pm 0.34$	31	22	$9.95 \pm 0.36$

Results of the paired samples t-tests/Wilcoxon signed rank tests are presented in Tables 5.4 and 5.5, respectively. Results from the repeated measures ANOVAs which were used to examine the difference in height changes from pre- to post-intervention between the intervention and control for the 6 and 10 year olds are also presented in Tables 5.4 and 5.5, respectively. As the repeated measures ANOVAs for both 6 and 10 year olds revealed significantly larger increases in height from pre- to post-intervention among the intervention groups when compared to the control groups ( $p < 0.01$ , large effect sizes), repeated measures ANCOVAs were used to examine the effectiveness of the intervention on markers of health while controlling for height i.e. change in height was entered as a covariate. The intervention effects for PA are presented in Table 5.6. ANCOVA results revealed that the WC SDS of the both 6 and 10 year old intervention groups increased by a significantly smaller amount from pre- to post-intervention compared to those of the control groups ( $p < 0.05$ , large and medium effect sizes for 6 and 10 year olds, respectively). The WC of the 6 year old intervention group increased by a significantly smaller amount than that of the control group, from pre- to post-intervention ( $p < 0.01$ , large effect size). The difference in WHtR between the 6 year old intervention and 6 year old control group increased significantly from pre- to post-intervention ( $p < 0.01$ , large effect size), with an insignificant decrease in WHtR found among the intervention group and a significant increase revealed among the control group ( $p < 0.01$ ). The SBP of the 6 year old control group decreased significantly more

from pre- to post-intervention than those of the 6 year old intervention group ( $p < 0.05$ , small effect size). The 550m time SDS of the 10 year old control group improved significantly more from pre- to post-intervention than the 550m time SDS of the 10 year old intervention group ( $p < 0.01$ , medium effect size). There was no significant difference between the 6 year old intervention and control group, nor the 10 year old intervention and control group from pre- to post-intervention for any of the measured FMS variables ( $p > 0.05$ ) (Tables 5.5 and 5.6). There were also no significant difference between the intervention and control group from pre- to post-intervention for any of the measured PA variables ( $p > 0.05$ ) (Table 5.6).

**Table 5.4:** Pre- and post-intervention data for 6 year olds from the intervention and control groups

	Intervention				Mean Difference	Control				Mean Difference	Group* Time	Partial Eta Squared	Effect Size*
	N	Pre	Post	p		N	Pre	Post	p				
Height (cm)	50	114.63 ± 6.07	118.39 ± 6.20	<0.001	3.76 ± 0.09	50	116.42 ± 4.39	119.44 ± 4.53	<0.001	3.02 ± 0.09	<0.001	0.241	Large
Mass (kg)	50	21.57 ± 3.23	23.09 ± 3.51	<0.001'	1.52 ± 0.09	50	21.38 ± 2.72	22.75 ± 2.97	<0.001'	1.37 ± 0.09	0.914	<0.001	-
<b>Markers of Health</b>													
BMI (kg/m <sup>2</sup> )	50	16.38 ± 1.81 <sup>a</sup>	16.44 ± 1.87	0.329'	0.11 ± 0.06 <sup>a</sup>	50	15.73 ± 1.38	15.90 ± 1.44	0.010'	0.12 ± 0.06 <sup>a</sup>	0.903''	<0.001	-
BMI SDS	50	0.47 ± 0.96	0.45 ± 0.96	0.499'	0.00 ± 0.04 <sup>a</sup>	50	0.08 ± 0.90	0.15 ± 0.90	0.115	0.04 ± 0.04 <sup>a</sup>	0.526	0.004	-
SBP SDS	49	-0.61 ± 1.28	1.13 ± 1.27	0.308'	-0.20 ± 0.19 <sup>a</sup>	49	-0.19 ± 0.99	-1.00 ± 1.07	<0.001'	-0.78 ± 0.19 <sup>a</sup>	0.051	0.039	-
DBP SDS	49	0.59 ± 1.31	0.13 ± 0.84	0.134'	-0.51 ± 0.19 <sup>a</sup>	49	0.67 ± 1.07	-0.28 ± 0.89	<0.001	-0.89 ± 0.19 <sup>a</sup>	0.187	0.018	-
SBP (mmHg)	49	99.20 ± 10.90	98.18 ± 9.20	0.502	-1.33 ± 1.60 <sup>a</sup>	49	103.14 ± 8.50	96.52 ± 8.65	<0.001'	-6.31 ± 1.60 <sup>a</sup>	0.041	0.043	Small
DBP (mmHg)	49	60.96 ± 11.09	56.66 ± 7.12	0.054'	-4.90 ± 1.58 <sup>a</sup>	49	61.45 ± 9.01	53.74 ± 6.98	<0.001'	-7.10 ± 1.58 <sup>a</sup>	0.357	0.009	-
HR (bpm)	49	89.24 ± 13.67	82.88 ± 12.25	0.002	-7.50 ± 1.90 <sup>a</sup>	49	86.49 ± 11.70	82.39 ± 11.02	0.010	-2.97 ± 1.90 <sup>a</sup>	0.117	0.026	-
WC (cm)	49	53.78 ± 3.91	54.96 ± 4.79	0.002'	1.04 ± 0.35 <sup>a</sup>	49	51.76 ± 3.39	55.89 ± 3.11	<0.001	4.28 ± 0.35 <sup>a</sup>	<0.001	0.280	Large
WC SDS	49	0.39 ± 1.03	0.54 ± 1.02	0.106'	0.12 ± 0.09 <sup>a</sup>	49	-0.20 ± 0.96	0.77 ± 0.73	<0.001	1.01 ± 0.09 <sup>a</sup>	<0.001	0.298	Large
WHtR	49	0.47 ± 0.04	0.47 ± 0.04	0.064'	-0.01 ± 0.00 <sup>a</sup>	49	0.45 ± 0.03	0.47 ± 0.02	<0.001	0.02 ± 0.00 <sup>a</sup>	<0.001	0.288	Large
550m time (secs)	47	223.26 ± 28.71	209.19 ± 28.59	<0.001'	-14.32 ± 3.13 <sup>a</sup>	47	206.91 ± 19.57	197.68 ± 21.10	<0.001	-9.27 ± 3.05 <sup>a</sup>	0.280	0.013	-
550m time SDS	47	0.96 ± 0.75	0.70 ± 0.80	0.012	-0.23 ± 0.10 <sup>a</sup>	47	0.61 ± 0.62	0.41 ± 0.72	0.007	-0.24 ± 0.09 <sup>a</sup>	0.973	0.000	-
<b>FMS</b>													
LOCO (range 0-48)	46	38.20 ± 4.36	40.91 ± 2.84	0.001'	2.72 ± 0.61	50	39.94 ± 3.43	41.48 ± 2.95	0.004	1.54 ± 0.59	0.168	0.020	-
OC (range 0-48)	46	27.93 ± 6.12	30.13 ± 5.81	0.006'	2.20 ± 0.75	52	30.37 ± 4.96	32.08 ± 5.31	0.026	1.71 ± 0.70	0.638	0.002	-
TOTAL FMS (range 0-96)	45	65.91 ± 7.93	70.84 ± 6.55	<0.001	4.93 ± 1.02	50	70.12 ± 5.45	73.58 ± 6.11	0.001'	3.46 ± 0.96	0.296	0.012	-

" = Height change was a significant covariate

<sup>a</sup> = Adjusted mean having controlled for height change as a covariate

Group\*Time = group by time interaction effect

\*Effect size only presented if group\*time was significant

'Wilcoxon signed rank test

**SBP** = systolic blood pressure; **DBP** = diastolic blood pressure; **HR** = heart rate; **WC** = waist circumference; **WHtR** = waist circumference-to-height ratio; **LOCO** = locomotor subset score; **OC** = object-control subset score

**Table 5.5:** Pre- and post-intervention data for 10 year olds from the intervention and control groups

	Intervention				Mean Difference	Control				Mean Difference	Group *Time	Partial Eta Squared	Effect Size*
	N	Pre	Post	p		N	Pre	Post	p				
Height (cm)	57	140.50 ± 6.29	144.12 ± 6.53	<0.001	3.62 ± 0.14	51	140.33 ± 5.38	143.12 ± 5.43	<0.001	2.79 ± 0.15	<0.001	0.138	Large
Mass (kg)	57	36.41 ± 7.81	38.76 ± 8.47	<0.001'	2.36 ± 0.23	51	35.65 ± 6.35	37.89 ± 6.87	<0.001'	2.24 ± 0.25	0.296	0.010	-
<b>Markers of Health</b>													
BMI (kg/m <sup>2</sup> )	57	18.33 ± 3.07	18.53 ± 3.07	0.017'	0.20 ± 0.11 <sup>a</sup>	51	18.03 ± 2.52	18.42 ± 2.65	0.001'	0.40 ± 0.11 <sup>a</sup>	0.226	0.014	-
BMI SDS	57	0.58 1.07	0.53 1.04	0.179	-0.05 ± 0.04 <sup>a</sup>	51	0.50 0.96	0.52 1.01	0.670	0.02 ± 0.04 <sup>a</sup>	0.280	0.011	-
SBP SDS	57	-0.60 1.19	-0.45 1.04	0.329	0.07 ± 0.16 <sup>a</sup>	50	-1.12 1.15	-1.28 1.10	0.404'	-0.07 ± 0.17 <sup>a</sup>	0.578	0.003	-
DBP SDS	57	0.62 1.01	0.43 0.90	0.139	-0.18 ± 0.17 <sup>a</sup>	50	0.52 1.19	0.25 1.26	0.076'	-0.29 ± 0.18 <sup>a</sup>	0.674	0.002	-
SBP(mmHg)	57	104.15 ± 11.16	105.93 ± 9.82	0.164'	1.05 ± 1.48 <sup>a</sup>	50	99.95 ± 10.54	98.42 ± 9.96	0.387'	-0.69 ± 1.59 <sup>a</sup>	0.439	0.006	-
DBP (mmHg)	57	62.15 ± 8.76	60.29 ± 7.52	0.159'	-1.77 ± 1.48 <sup>a</sup>	50	61.83 ± 10.81	59.06 ± 12.00	0.045'	-2.55 ± 1.58 <sup>a</sup>	0.727	0.001	-
HR (bpm)	57	82.88 ± 11.07	79.34 ± 11.55	0.032'	-3.08 ± 1.51 <sup>a</sup>	50	81.14 ± 12.60	82.97 ± 13.47	0.143'	1.32 ± 1.63 <sup>a</sup>	0.059	0.034	-
WC (cm)	57	61.82 ± 8.18	64.81 ± 9.28	<0.001'	3.02 ± 0.40 <sup>a</sup>	49	60.07 ± 5.60	64.04 ± 5.33	<0.001'	3.94 ± 0.43 <sup>a</sup>	0.132	0.022	-
WC SDS	57	0.65 ± 1.15	0.91 ± 1.16	<0.001	0.26 ± 0.07 <sup>a</sup>	49	0.39 ± 0.94	0.93 ± 0.76	<0.001'	0.53 ± 0.07 <sup>a</sup>	0.011	0.061	Med
WHtR	57	0.44 ± 0.05	0.45 ± 0.06	0.002'	0.01 ± 0.00 <sup>a</sup>	49	0.43 ± 0.04	0.45 ± 0.03	<0.001'	0.02 ± 0.00 <sup>a</sup>	0.086	0.028	-
550m time (secs)	49	178.00 ± 43.44	157.96 ± 27.82	<0.001'	-17.44 ± 2.80 <sup>a</sup>	42	176.05 ± 27.59	153.79 ± 18.60	<0.001	-25.29 ± 3.04 <sup>a</sup>	0.071''	0.037	-
550m time SDS	49	0.48 ± 1.13	0.09 ± 0.92	<0.001'	-0.33 ± 0.08 <sup>a</sup>	42	0.72 ± 0.86	0.08 ± 0.79	<0.001'	-0.72 ± 0.08 <sup>a</sup>	0.001''	0.115	Med
<b>FMS</b>													
LOCO (range 0-48)	51	41.59 ± 4.21	43.04 ± 2.76	0.011'	1.45 ± 0.48	41	41.17 ± 3.12	42.54 ± 3.18	0.180'	0.83 ± 0.54	0.392	0.008	-
OC (range 0-48)	52	38.87 ± 3.92	38.94 ± 3.73	0.889	0.08 ± 0.54	44	39.57 ± 3.75	40.05 ± 3.33	0.416	0.48 ± 0.59	0.618	0.003	-
TOTAL FMS (range 0-96)	51	80.53 ± 6.11	82.10 ± 4.67	0.071'	1.57 ± 0.71	41	81.54 ± 4.37	82.39 ± 4.03	0.264'	0.85 ± 0.80	0.505	0.005	-

" = Height change was a significant covariate

<sup>a</sup> = Adjusted mean having controlled for height change as a covariate

Group\*Time = group by time interaction effect

\*Effect size only presented if group\*time was significant

Med = medium effect size

'Wilcoxon signed rank test

**SBP** = systolic blood pressure; **DBP** = diastolic blood pressure; **HR** = heart rate; **WC** = waist circumference; **WHtR** = waist circumference-to-height ratio; **LOCO** = locomotor subset score; **OC** = object-control subset score

**Table 5.6:** Pre- and post-intervention PA data for the intervention and control groups

	Intervention (N=11)			Mean Difference	Control (N=6)			Mean Difference	Group* Time	Partial Eta Squared	Effect Size*
	Pre	Post	p		Pre	Post	p				
Light PA (mins/day)	240.96 ± 42.93	255.02 ± 42.93	0.277	14.06 ± 11.64	266.10 ± 37.82	273.09 ± 50.04	0.638	6.99 ± 15.76	0.723	0.009	-
Moderate PA (mins/day)	36.65 ± 16.18	33.89 ± 9.08	0.346	-2.75 ± 3.88	40.78 ± 18.61	40.34 ± 15.13	0.920	-0.44 ± 3.88	0.638	0.015	-
Vigorous PA (mins/day)	20.41 ± 13.27	18.31 ± 10.81	0.678	-2.11 ± 4.11	17.31 ± 9.62	18.13 ± 11.47	0.715	0.82 ± 5.57	0.679	0.012	-
MVPA (mins/day)	54.31 ± 16.91	54.95 ± 25.49	0.922	0.64 ± 5.81	57.65 ± 24.69	58.90 ± 29.20	0.838	1.25 ± 7.87	0.951	0.000	-
Total PA (mins/day)	295.26 ± 50.16	309.97 ± 55.40	0.356	14.70 ± 14.11	323.75 ± 53.41	331.99 ± 70.18	0.624	8.24 ± 19.10	0.789	0.005	-
Weekday MVPA (mins/day)	51.77 ± 16.03	61.49 ± 29.76	0.260	9.71 ± 7.30	57.76 ± 25.14	59.30 ± 31.65	0.837	1.54 ± 9.88	0.516	0.029	-
Weekend MVPA (mins/day)	63.66 ± 24.66	44.51 ± 26.07	0.052	-19.15 ± 7.43	56.90 ± 24.86	58.36 ± 25.98	0.792	1.46 ± 10.05	0.120	0.153	-
% time spent in light PA (mins/day)	31.74 ± 6.70	32.81 ± 5.35	0.483	1.08 ± 1.34	34.95 ± 7.14	35.85 ± 6.89	0.537	0.91 ± 1.81	0.940	0.000	-
% time spent in moderate PA	4.49 ± 1.36	4.72 ± 2.09	0.503	0.23 ± 0.37	5.22 ± 1.88	5.25 ± 2.02	0.969	0.03 ± 0.51	0.748	0.007	-
% time spent in vigorous PA	2.64 ± 1.58	2.35 ± 1.37	0.627	-0.29 ± 0.48	2.24 ± 1.25	2.35 ± 1.44	0.745	0.10 ± 0.65	0.639	0.015	-
% time spent in MVPA	7.13 ± 2.20	7.07 ± 3.27	0.940	-0.06 ± 0.68	7.47 ± 3.13	7.60 ± 3.36	0.883	0.13 ± 0.93	0.874	0.002	-
% time spent in total PA	38.87 ± 7.65	39.89 ± 7.05	0.537	1.02 ± 1.51	42.41 ± 8.86	43.47 ± 8.71	0.582	1.04 ± 2.04	0.995	0.000	-
% time spent in weekday MVPA	6.62 ± 2.00	7.66 ± 3.50	0.283	1.04 ± 0.86	7.29 ± 3.13	7.59 ± 3.55	0.779	0.30 ± 1.17	0.618	0.017	-
% time spent in weekend MVPA	9.15 ± 3.72	6.24 ± 4.10	0.036	-2.91 ± 1.03	8.02 ± 3.44	7.69 ± 3.27	0.676	-0.33 ± 1.39	0.157	0.129	-

\*Effect size only present if group\*time was significant

^Wilcoxon signed rank test

**Total PA** = light PA + MVPA

The number and proportion of children categorised as 'overweight/obese' using IOTF cut-points (Cole et al., 2000) are presented in Table 5.7. There was no significant difference in the proportion of children in the 6 year old intervention group that were 'overweight/obese' when compared to the 6 year old control group at pre- or post-intervention ( $p>0.05$ ). Similar results were found among the 10 year olds. Among both the 6 and 10 year old cohorts, there was no significant pre-post intervention difference in the prevalence of 'overweight/obese' children among the intervention or control groups ( $p>0.05$ ). However, it should be noted that the sample sizes of the respective groups were small (6 year old intervention:  $n=50$ , 6 year old control:  $n=50$ , 10 year old intervention:  $n=57$ , 10 year old control:  $n=51$ ), which may have affected the results.

The prevalence of 'central obesity' (WHR  $\geq 0.50$ ) among the 6 and 10 year old intervention and control groups are presented in Table 5.8. There were no significant differences in the proportion of 'centrally obese' children between either the 6 or 10 year old intervention and control groups at pre- or post-intervention. There was also no significant differences found from pre- to post-intervention among any of the intervention or control groups ( $p>0.05$ ). However, the small sample sizes used may have influenced the results (6 year old intervention:  $n=49$ , 6 year old control:  $n=49$ , 10 year old intervention:  $n=57$ , 10 year old control:  $n=49$ ).

The number and proportion of children from the intervention and control groups who were classified 'high-normal/high' BP are presented in Table 5.9. Among both the 6 year old intervention and control groups, there were significant decreases in the proportion of children with 'high-normal/high' BP ( $p<0.05$ ). Among the 10 year olds, there was a significant decrease in the proportion of children with 'high-normal/high' BP among the control group only. However, there was no significant difference in the proportion of children in the intervention group that had 'high-normal/high' BP when compared to the control group at either pre- or post-intervention, among both 6 and 10 year old cohorts ( $p>0.05$ ). The sample sizes of the respective groups for this analysis were small (6 year old intervention:  $n=49$ , 6 year old control:  $n=49$ , 10 year old intervention:  $n=57$ , 10 year old control:  $n=50$ ) and so it should be noted that this may have affected the results.

**Table 5.7:** The proportion of ‘overweight/obese’ children in the intervention and control groups pre- and post-intervention

	Intervention			Control			Difference between intervention and control groups	
	Pre	Post	<i>p</i>	Pre	Post	<i>p</i>	Pre	Post
<b>6 year olds</b>								
Overweight/obese	6/50 (12%)	7/50 (14%)	0.317	3/50 (6%)	3/50 (6%)	1.000	0.487	0.318
<b>10 year olds</b>								
Overweight/obese	13/57 (22.8%)	12/57 (21.1%)	0.564	9/51 (17.6%)	10/51 (19.6%)	0.317	0.634	1.000

**Table 5.8:** The proportion of ‘centrally obese’ children in the intervention and control groups pre- and post-intervention

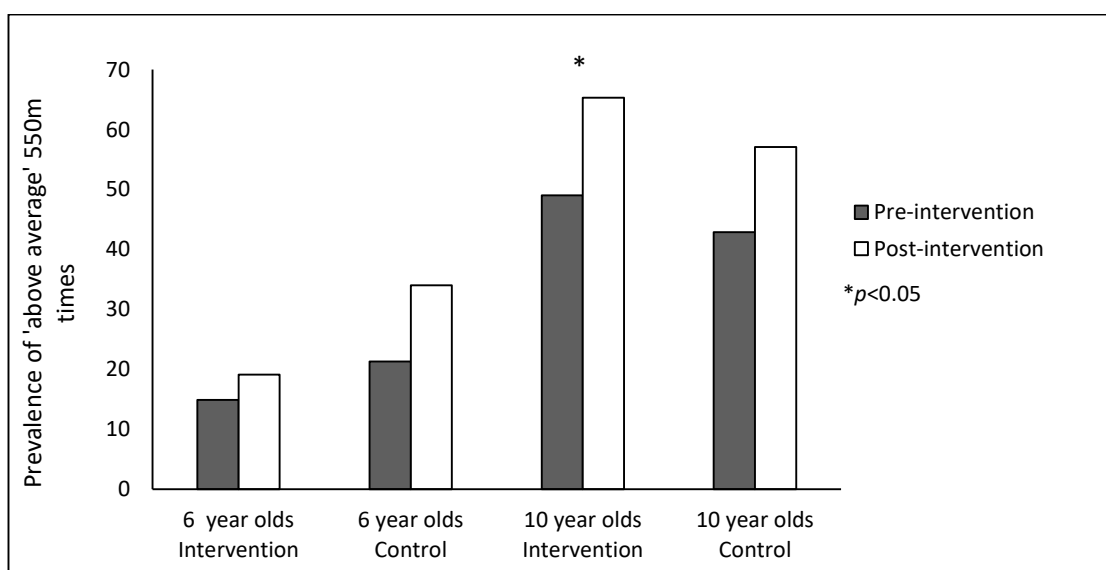
	Intervention			Control			Difference between intervention and control groups	
	Pre	Post	<i>p</i>	Pre	Post	<i>p</i>	Pre	Post
<b>6 year olds</b>								
WHtR ≥ 0.5 (centrally obese)	54/49 (89.8%)	44/49 (89.8%)	1.000	48/49 (98%)	45/49 (91.8%)	0.083	0.204	1.000
<b>10 year olds</b>								
WHtR ≥ 0.5 (centrally obese)	50/57 (87.7%)	49/57 (86%)	0.655	46/49 (93.9%)	44/49 (89.8%)	0.157	0.335	0.768

**Table 5.9:** The proportion of children with ‘high-normal/high’ BP in the intervention and control groups pre- and post-intervention

	Intervention			Control			Difference between intervention and control groups	
	Pre	Post	<i>p</i>	Pre	Post	<i>p</i>	Pre	Post
<b>6 year olds</b>								
High-Normal/High	15/49 (30.6%)	5/49 (10.2%)	0.004	14/49 (28.6%)	3/49 (6.1%)	0.005	1.000	0.715
<b>10 year olds</b>								
High-Normal/High	15/57 (26.3%)	10/57 (17.5%)	0.096	14/50 (28.0%)	4/50 (8.0%)	0.008	1.000	0.164



The proportion of children from the intervention and control groups who, based on sex and age-specific cut-points derived by Rush and Obolonkin (2014), had 'above average' 550m times are presented in Figure 5.2. Among the 6 year old cohort, there was no significant difference in the prevalence of 'above average' 550m times at post-intervention when compared to pre-intervention among both the intervention (pre-intervention: 14.9%, post-intervention: 19.1%,  $p>0.05$ ) and control (pre-intervention: 21.3%, post-intervention: 34%,  $p>0.05$ ) groups. Among the 10 year old intervention group, there was a significant increase in the proportion of children with above average 550m times following the intervention (pre-intervention: 49%, post-intervention: 65.5%;  $p<0.05$ ) while there was no significant difference among the respective control group (pre-intervention: 42.9%, post-intervention: 57.1%;  $p>0.05$ ). However, the results may have been influenced by the small sample sizes of the respective groups (6 year old intervention:  $n=47$ , 6 year old control:  $n=47$ , 10 year old intervention:  $n=49$ , 10 year old control:  $n=42$ ).



**Figure 5.2:** The proportion of 6 and 10 year old children from the intervention and control groups with 'above average' 550m run times pre- and post-intervention

The proportion of children from the intervention and control groups who were 'sufficiently active' i.e. whose average daily MVPA was equal to or exceeded 60 minutes/met the WHO's recommendation of at least 60 minutes MVPA, daily, on weekdays and weekend days are presented in Table 5.10. Although only 17 children

(intervention: n=11, control: n=6) provided pre- and post-intervention PA data, which may have influenced the result, it was found that there was no significant difference in the proportion of children meeting the recommendation from pre- to post-intervention among either the intervention or control groups ( $p>0.05$ ).

**Table 5.10:** The proportion of ‘sufficiently active’ children in the intervention and control groups pre- and post-intervention

	Intervention			Control			Difference between intervention and control groups	
	Pre	Post	<i>p</i>	Pre	Post	<i>p</i>	Pre	Post
All Days	4/11 (36.4%)	5/11 (45.5%)	0.564	2/6 (33.3%)	3/6 (50%)	0.317	0.904	0.862
Weekdays	3/11 (27.3%)	5/11 (45.5%)	0.317	2/6 (33.3%)	3/6 (50%)	0.317	0.799	0.862
Weekends	6/11 (54.5%)	3/11 (27.3%)	0.180	2/6 (33.3%)	2/6 (33.3%)	1.000	0.417	0.799

Process evaluation of the intervention revealed that the teachers felt that the Energized sessions maximised participation, were organised and could be effectively delivered with minimal equipment. Teachers reported that these sessions were fun, enjoyable and engaging for the children who were much more active than a typical PE lesson. The evaluation also found that teachers had noticed that there were improvements in children's fitness, spatial awareness, concentration, knowledge of the importance of being active daily, and that there was also a heightened awareness among children of their own fitness. Lack of time and facilities were identified as barriers for teachers to completing 20 minutes of PA with their classes every day. Teachers identified that providing sample quick and easy activities that could be delivered to children inside and outside the classroom could help teachers with the delivery of 20 minutes PA to their class every day. Other ways identified were providing help with gymnastics, a booklet of suitable activities, sample outdoor adventure based activities and breaking the 20 minutes down into shorter more frequent breaks throughout the day.

## **5.5. Discussion**

This PA intervention resulted in significantly smaller increases in WC SDS among the 6 and 10 year old intervention groups from pre- to post-intervention relative to their respective control groups (large and medium effect sizes for the 6 and 10 year olds, respectively). Among the 6 year olds, there were also significant positive intervention effects for WC and WHtR (both large effect sizes).

Given that central adiposity is associated with cardiometabolic health risk factors among children (Kelishadi et al., 2007), interventions such as that of the current study, that can positively impact central adiposity among children may have major public health implications. The relative decrease (i.e. the smaller increase) in WC SDS among the 6 and 10 year intervention groups when compared to the respective control groups was found with no difference between the intervention and control groups from pre- to post-intervention for BMI. While there was no difference between the intervention and control groups from pre- to post-intervention for BMI among either the 6 or 10 year old

cohorts, it is noteworthy that among the 6 year olds, there was a significant increase in BMI among the control group with no significant difference in BMI among the intervention group. This suggests that the intervention was effective at preventing an increase/maintaining BMI among the children in the intervention group.

Similar to Rush et al. (2012) who found a relative decrease in the body fat percentage, but not BMI, of 5 year old children from New Zealand following a 2 year PA intervention, the current study found a relative decrease in body fat (WHtR being used as a proxy for total fat) among 6 year olds, with no relative reduction in BMI. Furthermore, Rush et al. (2012) found no significant difference in either body fat percentage or BMI among the 10 year old intervention group relative to the control ( $p>0.05$ ), which again is similar to the current study which found no intervention effects for WHtR (a proxy measure of total fat (Santos, Severo, Lopes, & Oliveira, 2018)) or BMI among 10 year olds. (While there were significant positive intervention effects for WC SDS, this measure is an indicator of abdominal adiposity as opposed to total fat (Santos et al., 2018)).

No significant differences were reported for any of the measured PA variables. However, it should be noted that the sample size from which PA data was collected was very small, limiting any meaningful conclusions that could be drawn.

Despite a significantly greater improvement in 550m time SDS from pre- to post-intervention among the 10 year old control group relative to the intervention group for 550m time SDS, the significant increase in the proportion of children from the intervention group achieving above average 550m times at post-intervention is noteworthy and may explain the positive intervention effects found for heart rate among this group. These findings suggest that the CRF levels of the 10 year old intervention group increased as a result of the intervention. These findings support the delivery of interventions such as this PA intervention given the low CRF levels reported among Irish youth (Hudson et al., 2015) and existing evidence that highlights the importance of CRF for optimising adiposity levels, preventing CVD risk factors, positively effecting children's psychosocial health (such as depression, anxiety, mood, self-esteem) (Ortega, Ruiz, Castillo, & Sjostrom, 2008) and also academic achievements (Oliveira et

al., 2017; Ortega et al., 2008), even independent of PA level (Ekelund et al., 2007; Oliveira et al., 2017).

The intervention revealed no significant intervention effect for any of the FMS variables (locomotor, object-control or total FMS). These findings support those of Morgan et al. (2013) and Logan et al. (2011) who outlined that FMS specific interventions are more effective at enhancing FMS than typical PE classes or free play. While the intervention in the current study appeared to positively impact adiposity, PA and CRF among children, perhaps FMS specific activities/sessions in addition to huff and puff activities may be necessary to concurrently affect adiposity, PA, CRF and FMS. Findings reported by Cohen, Morgan, Plotnikoff, Callister, et al. (2015) from the evaluation of a 12-month FMS- and PA-based intervention on CRF, PA and FMS among children from low-income communities suggest that FMS- and PA-based interventions can have such an impact. However, to date no such intervention has been planned, implemented or evaluated among Irish primary school children and such an intervention is warranted.

This intervention was carried out over a 6 month period. As it has been suggested that longer interventions may be more effective (Dobbins et al., 2009; Kriemler et al., 2011), the intervention may produce even greater results if it were carried out over a 1-year period (Kriemler et al., 2011) or even 1 full academic year i.e. September-June. Findings from the SCORES intervention supports a longer intervention, as no significant intervention effects were observed at mid-program (6 months) ( $p>0.05$ ), but significant intervention effects for PA, CRF and FMS found at the end of the 12 month programme ( $p<0.05$ ).

#### Strengths and Limitations

Strengths of the study include the delivery of the intervention by specialists (a success-level determining factor suggested by Starc and Strel (2012)), and the use of a comprehensive objective battery of markers of health to evaluate the effectiveness of the intervention. While the study used an objective measure of PA, a limitation that must be noted is the very small sample size from which this data was collected. While the intervention appeared to have a positive impact on MVPA levels, research using much larger sample sizes should be conducted to allow meaningful conclusions to be

made. Furthermore, ideally PA data would be collected concurrently for both the intervention and control groups and under similar conditions at pre- and post-intervention with regards to weather and day-length. However, due to limited accelerometer availability, this was not feasible in the current study design, but something that future research should consider. Another strength of the study was the inclusion of a process evaluation, the results of which can be used to inform future interventions.

While Energizers encouraged and supported teachers (with the provision of activity break ideas, printed resources and a professional development workshop) to allow children to engage in at least 20 minutes of MVPA on the days on which no Energizer sessions took place, the amount of time teachers actually devoted to extra MVPA sessions was not measured and may not have occurred at all i.e. the Energizer sessions may have been the only intervention component to have impacted the results. Future research should therefore quantify the amount of time that teachers allocate to extra PA during the day and also attempt to address these identified barriers in an attempt to increase children's MVPA levels. The process evaluation of the current intervention found that teachers felt that 'time constraints' and 'lack of facilities' were the two main barriers to completing 20 minutes MVPA with their class every day. Future interventions that aim for teachers to allow children to engage in 20 minutes MVPA every day should consider dividing the 20 minute period into shorter more frequent breaks across the school day e.g. 4 x 5 minute activity breaks. Furthermore, a booklet of suitable classroom based activities should be provided to help teachers facilitate these shorter, more frequent breaks that are likely to be completed indoors.

## **5.6 Conclusion**

This study suggests that primary school PA interventions can positively impact the adiposity levels of children and the CRF of 10 year old children. Given the current obesity epidemic and the low CRF levels of Irish children, the inclusion of PA interventions in Irish primary schools should be considered. However, it should be noted that the study

found no intervention effects for FMS proficiency, suggesting that an FMS specific intervention may be necessary to improve both FMS proficiency and markers of health.



**Chapter 6:**  
**The effectiveness of a tailored motor skill  
intervention on the fundamental movement skill  
proficiency and markers of health among a cohort  
of Irish primary school children**

## 6.1 Abstract

**Background:** Fundamental movement skill (FMS) proficiency is positively associated with health among children. It has been found that FMS-based interventions can positively affect FMS competence and markers of health among children. The FMS proficiency, PA, CRF and overweight/obesity levels of Irish primary school children is poor, yet no specific FMS-based intervention has been designed, delivered or evaluated among Irish primary school children. The purpose of this study was to evaluate the effectiveness of a motor skill intervention on FMS and markers of health among a cohort of Irish primary school children. **Methods:** A 26-week Project Spraoi FMS and PA intervention was evaluated among 6 (senior infants and 1<sup>st</sup> class) and 10 year old (4<sup>th</sup> and 5<sup>th</sup> class) children (N=466) from 3 primary schools in Co. Cork, Ireland. FMS proficiency (Test of Gross Motor Development-2; Ulrich, 2000) and the following markers of health; BMI, BP, heart rate, CRF (550m walk/run) and objectively measured PA via accelerometry), were recorded pre- and post-intervention. **Results:** There were significant, positive intervention effects among both 6 and 10 year olds for locomotor ( $p<0.01$ ,  $\eta_p^2=0.266$  and  $\eta_p^2=0.286$  for 6 and 10 year olds respectively, large effect sizes), object-control ( $p<0.01$ ,  $\eta_p^2=0.333$  and  $\eta_p^2=0.299$  for 6 and 10 year olds respectively, large effect sizes), and total FMS ( $p<0.01$ ,  $\eta_p^2=0.454$  and  $\eta_p^2=0.446$  for 6 and 10 year olds respectively, large effect sizes). There were positive intervention effects for BMI ( $p<0.05$ ,  $\eta_p^2=0.045$ , small effect size) and BMI SDS ( $p<0.05$ ,  $\eta_p^2=0.073$ , medium effect size) among 6 year olds and BMI SDS ( $p<0.05$ ,  $\eta_p^2=0.026$ , small effect size), HR ( $p<0.01$ ,  $\eta_p^2=0.050$ , small effect size) and 550m time SDS ( $p<0.05$ ,  $\eta_p^2=0.045$ , small effect size) among 10 year olds. There was also a significant decrease in the prevalence of overweight/obesity ( $p<0.05$ ) and an increase in the proportion of children achieving above average 550m times among the 6 and 10 year old intervention groups following the intervention ( $p<0.05$ ).

**Conclusion:** A school-based multi-component FMS-based intervention improved BMI SDS, FMS proficiency and CRF among a cohort of Irish primary school children.

**Keywords:** cardiorespiratory fitness, elementary school, locomotor, object-control, physical activity, overweight/obesity

## 6.2 Introduction

The World Health Organisation (WHO) recommend that children and youth aged 5-17 years engage in at least 60 minutes of MVPA every day (WHO, 2017e). Despite these recommendations and the reported health benefits associated with PA (Janssen & LeBlanc, 2010), less than 80% of Irish children engage in 60 minutes or more MVPA daily (Economic and Social Research Institute, 2009; Woods et al., 2010). These low PA levels for children may be linked with the poor CRF levels (Hudson et al., 2015; Woods et al., 2010), and the high prevalence of overweight/obesity reported among Irish youth (Bel-Serrat et al., 2017; Woods et al., 2010).

The identification of PA facilitators and barriers is crucial so that effective interventions that can increase children's PA levels, and in turn improve health are to be developed (Hesketh, Lakshma, & van Sluijs, 2017). One such facilitator for childhood PA promotion that has been identified, is the development of FMS (Stodden et al., 2008). FMS are basic movement skills such as running, jumping and throwing. They are the 'building blocks' upon which more complex sports, games and PA skills are based (Logan, Ross, Chee, Stodden, & Robinson, 2018). For instance, O'Keeffe et al. (2007) found that the technique used in the performance of the overarm throw (an FMS), transfers to the execution of the badminton clear and javelin throw. FMS consist of three categories; locomotor, object-control, and balance/stability (Logan et al., 2018).

Stodden et al. (2008) suggested that moderate and high FMS competence contribute to higher perceived competence and higher PA levels, which in turn have positive effects on adiposity levels and health related fitness. Research has supported these suggestions with positive relationships between FMS and perceived competence (Barnett, Ridgers, & Salmon, 2015), FMS and PA (Fisher et al., 2005), FMS and CRF (Burns et al., 2017), FMS and health related fitness (Luz, Rodrigues, De Meester, & Cordovil, 2017) reported. A negative relationship between FMS and adiposity level (Slotte et al., 2015) has also been found. Given the low FMS proficiency of children (Bardid, Huyben, et al., 2016; Bolger et al., 2017; Spessato, Gabbard, Valentini, et al., 2013) and the positive relationships

between FMS and health, the development of FMS proficiency among children may positively impact markers of health.

The low FMS (Bolger et al., 2017; Farmer et al., 2017), PA (Woods et al., 2010) and CRF levels (Hudson et al., 2015; Woods et al., 2010) and the high prevalence of overweight/obesity among Irish youth (Bel-Serrat et al., 2017) highlight that interventions for FMS and health promotion in children are warranted. A PA intervention carried out among primary school children that involved the delivery of 2 x 25 minute high-intensity games based sessions per week resulted in significant positive intervention effects on children's adiposity levels, and provided encouraging findings that suggest improvements in PA may also occur (Chapter 5). However, no concurrent intervention effects were found for children's overall FMS proficiency levels. These findings indicate that the study design may need to be adapted to incorporate an FMS focus to achieve positive intervention effects for both FMS and markers of health. PA interventions evaluated by Verstraete, Cardon, de Clerq, and Bourdeaudhuij (2007) among 764 elementary school children (mean age:  $11.2 \pm 0.7$  years) and Walther et al. (2009) among 182 children (mean age:  $11.1 \pm 0.7$  years), reported similar findings to those of the PA intervention (Chapter 5) in that positive intervention effects were found for markers of health (namely PA and fitness), but not for motor skills. Thus, FMS-based interventions may be necessary for improvements in both FMS and markers of health. Reviews by Morgan et al. (2013), Logan et al. (2011) and Tompsett et al. (2017) emphasise the need for FMS specific interventions to improve children's FMS proficiency. Furthermore, (Tompsett et al., 2017) reported that in addition to FMS improvements, FMS specific interventions can also have a positive impact on physiological (e.g. CRF, adiposity level), psychological (e.g. perceived competence) and behavioural (e.g. PA) outcomes among children.

While an FMS intervention conducted among Irish adolescents has produced positive findings for FMS and PA (O'Brien et al., 2013), no such intervention has been planned, implemented or evaluated among a cohort of Irish primary school children. The aim of the current study is therefore to evaluate the effectiveness of a tailored FMS-based

intervention on a comprehensive battery of markers of health, and FMS proficiency among a cohort of Irish primary school children.

### **6.3 Methods**

#### Participants

Children from two intervention (one urban single-sex boys, and one urban single-sex girls) schools, and one (rural mixed) control school in Cork (a region in southern Ireland) were invited to participate in the study. Children in the two intervention schools had previously participated in a PA intervention during the previous academic year (2014/2015), while the control school used in the current study was the control school used in the evaluation of the PA intervention carried out during 2014/2015. Participating schools were medium in size (100-300 children), and situated in close proximity (within 20km) to the research institute following Project Spraoi inclusion criteria (Coppinger et al., 2016).

The tailored FMS-based intervention was delivered to all children enrolled in the intervention schools, while children from the selected senior infants, 1<sup>st</sup>, 4<sup>th</sup> and 5<sup>th</sup> class cohort were invited to participate in the evaluation of the intervention only (junior infants, 2<sup>nd</sup>, 3<sup>rd</sup>, and 6<sup>th</sup> class not involved in the research evaluative component of the project). Of the 605 children invited to participate in the evaluation, a total of 466 provided written assent and parental consent (77% consent rate). Ethical approval for the study was granted from Cork Institute of Technology Research Ethics Review Board in September 2014.

#### FMS

FMS proficiency was measured using the Test of Gross Motor Development-2 (TGMD-2) (Ulrich, 2000). A total of 12 skills; 6 locomotor (run, leap, hop, gallop, slide, horizontal jump) and 6 object-control (catch, throw, underhand roll, kick, two-handed strike, stationary dribble) skills were assessed. Locomotor, object-control and total FMS scores

were calculated. The procedures used to collect and analyse FMS data are outlined in Chapter 3.

### Physical Measurements

Physical measurements recorded were height, mass, heart rate and BP. These measures were taken as outlined in Chapter 3. The mean of the closest two measurements for each variable was calculated. This value was then used in the analysis.

BMI was calculated as weight in kilograms divided by height in metres squared. These values were then used to categorise children as 'non-overweight' or 'overweight/obese' based on the age- and sex-specific International Obesity Task Force (IOTF) BMI cut-points (Cole et al., 2000). Standard deviation scores for BMI and BP were calculated from the British 1990 child growth reference data for age- and sex-specific SDS for BMI (Cole et al., 1995), and SBP and DBP (Jackson et al., 2007). Based on the age- and sex-specific BP centiles of Jackson et al. (2007), children were classified as having either 'normal' ( $\leq 91^{\text{st}}$  centile) or 'high-normal/high' BP ( $> 91^{\text{st}}$  centile).

### CRF

The 550m run/walk test (Albon et al., 2010), a valid measure of CRF among children (Hamlin et al., 2014) was used as an assessment of children's CRF. A detailed account of the testing protocol is reported in Chapter 3. Time taken to complete the 550m was recorded for each child to the nearest second. The time taken to complete the 550m was not recorded if a child stopped for a period longer than five seconds or if they did not complete the full 550m distance (Hamlin et al., 2014). The run centile curves developed by 'Project Energize' evaluation data (Rush & Obolonkin, 2014) were used to calculate age- and sex-specific 550m time standard deviation scores and also to categorise children into one of two 550m run/walk categories; above average ( $\geq 50^{\text{th}}$  centile) or below average ( $< 50^{\text{th}}$  centile).

### PA

PA data were recorded using ActiGraph GT3X and GT3X+ tri-axial accelerometers. Children were instructed to wear the accelerometers on their right hip for 7 consecutive days at all times (except when sleeping and engaging in water-based activities such as

swimming and bathing). Data were collected, stored and analysed using the procedures outlined in Chapter 3. The quantity of time spent in light PA, moderate PA, vigorous PA, MVPA and total PA were calculated using the cut-points of Evenson et al. (2008). Each child's mean weekday MVPA, and mean weekend day MVPA were also calculated. Based on recommendations of the World Health Organisation that outline that children should spend a minimum of 60 minutes each day in MVPA (WHO, 2017e), each child's mean daily MVPA, mean weekday MVPA and mean weekend day MVPA were then used to categorise them as 'sufficiently active' i.e. the time they spent in MVPA exceeded 60 minutes or 'not sufficiently active' i.e. the time they spent engaged in MVPA was less than 60 minutes, across all days (weekday and weekend day MVPA combined before calculating mean daily MVPA), weekdays and weekend days. Due to limited accelerometer availability, PA data was only collected from a subsample of children. At pre-intervention, a total of 247 children received accelerometers. However, as only those who met the wear time criteria of at least 600 minutes on three weekdays and one weekend day at both pre- and post-intervention data from 67 children (senior infant/1<sup>st</sup> class: n=32, 4<sup>th</sup>/5<sup>th</sup> class: n=35) (27.1% of those who received accelerometers and 14.4% of the total sample) were included in the final analysis.

#### Perceived FMS Competence

Children's FMS perceived competence was measured using the Pictorial Scale of Perceived Movement Skill Competence (Barnett, Ridgers, Zask, et al., 2015) which has been found to be valid and reliable among 5-10 year old children (Barnett, Ridgers, Zask, et al., 2015; Barnett, Robinson, et al., 2015; Diao, Barnett, Estevan, Dong, & Li, 2018; Lopes et al., 2016; Valentini et al., 2018). This test was administered on a one-to-one basis by a trained research evaluator. Children assessed their competence in the 12 FMS of the TGMD-2. Children were presented with cartoon images of children performing the given FMS. One child was competent at performing the skills, and one child was not. Children were asked whether they felt they were more like the child who was 'good' at performing the skill, or the child who was 'not so good' at performing the skill. Depending on their response, children were subsequently asked whether they felt they were 'very good' or 'pretty good', at performing the skills, or alternatively 'not very good' or 'sort of good', at performing the skill. Perceived competence scores for each

skill ranged from 1 to 4 (1=not very good, 2=sort of good, 3=pretty good, 4=very good) with higher scores indicating higher perceptions of skill competence.

### Intervention

The multi-component FMS-based intervention was carried out across 26 academic weeks between October 2015 and May 2016. The intervention was primarily delivered by the Energizer with the classroom teachers also playing a critical role in the delivery of the programme. A detailed account of the FMS intervention is provided in Chapter 3. In summary, the intervention included the delivery of 2 x 25 minute FMS-based lessons to each class per week, the design and distribution of FMS promoting material (posters and homework manuals), teacher training (professional development workshops and an FMS teacher manual) and a number of PA initiatives (to encourage teachers to facilitate children's engagement in at least 20 minutes of MVPA throughout class time every day). With 12 specific FMS identified to cover throughout the intervention, a two week period of focus was dedicated to each skill. The final two weeks of the intervention were then dedicated to those FMS that the children found particularly difficult to execute. These skills were the catch, dribble and hop.

### Process Evaluation

A detailed description of the methods used to conduct the process evaluation of the intervention is provided in Chapter 3. In summary, the process evaluation included (i) teacher questionnaires (one completed at mid-programme and one at the end of the programme (Appendix F.1), (ii) a write and draw activity (Appendix F.2) completed by children from the intervention schools, and (iii) interviews with a randomly selected subsample of children (n=8) from the intervention schools.

### Statistical Analysis

Data analysis was conducted using SPSS version 22. Children were divided into 6 (senior infant and 1<sup>st</sup> class) and 10 year old (4<sup>th</sup> and 5<sup>th</sup> class) groups for analysis. Assuming a significance level of 0.05 and power of 0.8, it was determined that a sample of 34 children was needed to detect statistically significant medium effect size. Due to the limited sample size from which valid PA data was collected, children from both age



categories were grouped together for the analysis of this data. Only children with both pre- and post-intervention data (for each of the measured variables) were included in the final analysis. Means, standard deviations and frequencies are used to summarise the data. Data were assessed for normality. When data was normally distributed, paired samples t-tests were used to investigate differences in variables over time (i.e. between pre- and post-intervention). Paired samples t-tests were used to examine the pre- to post-intervention change in the 6 year old intervention group's height, SBP SDS, DBP SDS, DBP, heart rate and 550m time SDS, the 6 year old control group's height, BMI SDS, SBP SDS, DBP SDS, SBP, DBP, HR, 550m time SDS, OC and total FMS scores, the 10 year old intervention group's height, BMI SDS, SBP SDS, DBP SDS and the 10 year old control group's height, BMI SDS, SBP SDS, DBP SDS, SBP, DBP, 550m time SDS, OC and total FMS scores. When data were not normally distributed, Wilcoxon signed rank tests were used. Wilcoxon signed rank tests were used to examine the pre- to post-intervention change in the 6 year old intervention group's mass, BMI, BMI SDS, SBP, 550m time, LOCO, OC, total FMS, PC LOCO, PC OC and PC total FMS, the 6 year old control group's mass, BMI, SBP, 550m time, LOCO, PC LOCO, PC OC and PC total FMS scores, the 10 year old intervention group's mass, BMI, DBP, HR, 550m time SDS, LOCO, OC, total FMS, PC LOCO, PC OC and PC total FMS scores and the 10 year old control group's mass, BMI, HR, 550m time, LOCO, PC LOCO, PC OC and PC total FMS scores. Repeated measures ANOVAs were used to investigate if there were any differences from pre- to post-intervention with respect to group (intervention and control) for height, FMS, perceived FMS competence and PA. Repeated measures ANCOVAs were run to investigate if there were any differences from pre- to post-intervention with respect to group (intervention and control) for the remaining markers of health i.e. to assess the effectiveness of the intervention on the measured markers of health while adjusting for change in height from pre- to post-intervention. When the group\*time interaction i.e. when the difference between the intervention and control groups from pre- to post-intervention, was significant, partial eta squared values were examined to determine the size of effect (Cohen, 1969). Partial eta squared values of 0.0099, 0.0588 and 0.1379 were used as benchmarks for small, medium and large effect sizes, respectively (Cohen, 1969).

Chi-squared tests were used to investigate if there were differences between the intervention and control groups for the proportion of children who achieved the recommended 60 minutes MVPA daily (i.e. were sufficiently active), had high-normal/high BP and who had above average age- and sex-specific 550m times. Cochran Q tests were used to identify any significant pre- to post-intervention differences in these measures among the intervention and control groups. The significance level for all statistical tests was set at  $p < 0.05$ .

## 6.4 Results

A total of 466 children (intervention  $n=266$ ; control  $n=200$ ) participated in the evaluation of the intervention. Information relating to the children who participated in the evaluation is presented in Table 6.1.

**Table 6.1:** Information relating to the children who participated in the study

	6 year olds (n=222)			10 year olds (n=244)		
	Boys (n)	Girls (n)	Age (Mean $\pm$ SD)	Boys (n)	Girls (n)	Age (Mean $\pm$ SD)
Intervention (n=266)	67	60	6.32 $\pm$ 0.61	72	67	10.39 $\pm$ 0.63
Control (n=200)	47	48	6.61 $\pm$ 0.59	62	43	10.51 $\pm$ 0.53

Paired samples t-test/Wilcoxon signed rank test, repeated measures ANOVA and ANCOVA results for physical, CRF, FMS and perceived FMS measures are presented for the 6 year old intervention and control groups in Table 6.2 and for the 10 year old intervention and control groups in Table 6.3. The intervention effects for PA measures are presented in Table 6.4.

The repeated measures ANOVA revealed the intervention groups grew significantly taller from pre- to post-intervention than their counterparts in the control groups ( $p < 0.01$ , large effect sizes). ANCOVA results revealed that the difference between the 6 year old intervention and control groups from pre- to post intervention increased significantly for BMI ( $p < 0.05$ , small effect sizes), with significant decreases revealed

among the intervention groups ( $p < 0.01$ ) and significant increases among the control groups ( $p < 0.05$ ). Among both 6 and 10 year old groups, there were significantly larger improvements found across time i.e. from pre- to post-intervention, among the intervention groups relative to the control groups for BMI SDS ( $p < 0.05$ , medium and small effect sizes, respectively). There was a significantly larger improvement in 550m time SDS among the 10 year old intervention group compared to the control from pre- to post-intervention ( $p < 0.05$ , small effect size). The difference in DBP and DBP SDS between the 10 year old intervention and control groups increased significantly from pre- to post-intervention ( $p < 0.01$ , small effect sizes) with significant decreases in DBP and DBP SDS among the control group ( $p < 0.01$ ) and significant increases among the intervention group ( $p < 0.01$ ). There was a significantly larger decrease in heart rate found among the 10 year old intervention group from pre- to post-intervention relative to the control group ( $p < 0.05$ , small effect size). There was a significant increase in the difference between the intervention and control groups from pre- to post intervention for LOCO, OC and total FMS ( $p < 0.01$ , large effect sizes for all), with significant increases found among the intervention groups ( $p < 0.01$ ) and significant decreases among the control groups ( $p < 0.05$ ). The perceived OC competence of the 10 year old control group improved significantly more from pre- to post-intervention than the perceived OC competence of the 10 year old intervention group ( $p < 0.05$ , small effect size). In relation to the PA measures, the levels of the control group increased significantly more from pre- to post-intervention than those of the intervention for moderate PA, vigorous PA, MVPA, total PA, percentage of time spent in moderate PA, vigorous PA, MVPA and total PA ( $p < 0.05$ , medium effect sizes for all). There was also a significant increase in the difference between the intervention and control group across time for weekend MVPA and percentage of time spent in weekend MVPA ( $p < 0.05$ , large effect sizes), with no significant pre- to post-intervention differences among the intervention group for either measure and significant increases found among the control group ( $p < 0.01$

**Table 6.2:** Pre- and post-FMS intervention data for 6 year olds from the intervention and control groups

	Intervention				Mean Difference	Control				Mean Difference	Group* Time	Partial Eta Squared	Effect Size*
	N	Pre	Post	p		N	Pre	Post	p				
Height (cm)	119	118.14 ± 6.46	125.44 ± 6.59	<0.001	7.30 ± 0.08	84	119.91 ± 5.88	124.16 ± 6.08	<0.001	4.24 ± 0.10	<0.001	0.743	Large
Mass (kg)	119	22.97 ± 3.88	24.67 ± 4.21	<0.001'	1.70 ± 0.10	84	23.28 ± 3.67	25.04 ± 4.42	<0.001'	1.76 ± 0.12	<0.001	0.062	Med
<b>Markers of Health</b>													
BMI (kg/m <sup>2</sup> )	119	16.39 ± 1.93	15.60 ± 1.75	<0.001'	-0.68 ± 0.09 <sup>a</sup>	84	16.11 ± 1.52	16.16 ± 1.84	0.012'	-0.11 ± 0.12 <sup>a</sup>	0.002	0.045	Small
BMI SDS	119	0.40 ± 1.05	-0.18 ± 1.07	<0.001'	-0.55 ± 0.05 <sup>a</sup>	84	0.25 ± 0.87	0.14 ± 0.97	0.003	-0.15 ± 0.07 <sup>a</sup>	<0.001	0.073	Med
SBP SDS	114	-0.64 ± 1.12	-0.65 ± 0.99	0.950	-0.26 ± 0.16 <sup>a</sup>	81	-0.48 ± 1.08	-0.59 ± 0.95	0.426	0.26 ± 0.21 <sup>a</sup>	0.109''	0.013	-
DBP SDS	114	0.52 ± 1.01	0.45 ± 0.76	0.488	0.06 ± 0.15 <sup>a</sup>	81	0.33 ± 0.95	0.22 ± 0.81	0.355	-0.30 ± 0.19 <sup>a</sup>	0.241	0.007	-
SBP (mmHg)	114	98.98 ± 9.69	99.78 ± 8.44	0.071'	-1.45 ± 1.38 <sup>a</sup>	81	100.70 ± 9.27	100.65 ± 8.23	0.575'	3.12 ± 1.81 <sup>a</sup>	0.110''	0.013	-
DBP (mmHg)	114	59.77 ± 8.45	59.40 ± 6.22	0.673	0.75 ± 1.22 <sup>a</sup>	81	58.32 ± 7.81	57.60 ± 6.56	0.446	-2.29 ± 1.60 <sup>a</sup>	0.226	0.008	-
HR (bpm)	114	88.40 ± 12.90	86.16 ± 12.45	0.049	-0.61 ± 1.58 <sup>a</sup>	81	85.57 ± 11.70	81.90 ± 8.56	0.003	-5.96 ± 2.07 <sup>a</sup>	0.102	0.014	-
550m time (secs)	99	209.52 ± 27.56	185.07 ± 23.40	<0.001'	-18.42 ± 33.87 <sup>a</sup>	78	204.69 ± 24.75	186.41 ± 26.56	<0.001'	-24.44 ± 4.89 <sup>a</sup>	0.445	0.003	-
550m time SDS	99	0.70 ± 0.80	0.12 ± 0.82	<0.001	-0.47 ± 0.11 <sup>a</sup>	78	0.65 ± 0.73	0.22 ± 0.85	<0.001	-0.58 ± 0.14 <sup>a</sup>	0.646	0.001	-
<b>FMS</b>													
LOCO (range 0-48)	93	39.26 ± 3.87	43.03 ± 3.24	<0.001'	3.77 ± 0.40	82	39.18 ± 3.66	38.34 ± 3.91	0.053'	-0.84 ± 0.43	<0.001	0.266	Large
OC (range 0-48)	105	31.64 ± 5.10	36.34 ± 4.60	<0.001'	4.71 ± 0.50	79	33.78 ± 5.22	31.22 ± 5.18	<0.001	-2.57 ± 0.58	<0.001	0.333	Large
TOTAL FMS (range 0-96)	93	70.59 ± 6.72	79.29 ± 6.09	<0.001'	8.70 ± 0.69	77	73.18 ± 6.54	69.70 ± 6.71	<0.001	-3.48 ± 0.76	<0.001	0.454	Large
PC LOCO (range 0-24)	116	21.33 ± 2.62	21.55 ± 2.56	0.226'	0.22 ± 0.24	89	20.98 ± 2.61	21.25 ± 2.24	0.423'	0.27 ± 0.28	0.902	<0.001	-
PC OC (range 0-24)	116	20.53 ± 3.01	20.66 ± 2.59	0.738'	0.13 ± 0.26	89	20.18 ± 3.06	20.65 ± 2.48	0.158'	0.47 ± 0.30	0.394	0.004	-
PC TOTAL FMS (range 0-48)	116	41.86 ± 4.76	42.22 ± 4.18	0.264'	0.35 ± 0.40	89	41.16 ± 4.53	41.90 ± 3.43	0.170'	0.74 ± 0.46	0.526	0.002	-

" = Height change was a significant covariate

<sup>a</sup> = Adjusted mean having controlled for height change as a covariate

Group\*Time = group by time interaction effect

\*Effect size only presented if group\*time was significant

'Wilcoxon signed rank test

**SBP** = systolic blood pressure; **DBP** =diastolic blood pressure; **HR** = heart rate; **MVPA** = moderate-to-vigorous PA; **LOCO** = locomotor subset score; **OC** = object-control subset score; **PC LOCO**; perceived locomotor competence; **PC OC** =perceived object-control competence; **PC TOTAL FMS** = perceived FMS competence

**Table 6.3:** Pre- and post-FMS intervention data for 10 year olds from the intervention and control groups

	Intervention				Mean Difference	Control				Mean Difference	Group* Time	Partial Eta Squared	Effect Size*
	N	Pre	Post	p		N	Pre	Post	p				
Height (cm)	130	143.06 ± 7.07	150.31 ± 7.33	<0.001	7.25 ± 0.13	96	143.63 ± 5.83	147.87 ± 6.41	<0.001	4.24 ± 0.15	<0.001	0.517	Large
Mass (kg)	130	37.87 ± 8.80	41.16 ± 0.01	<0.001'	3.29 ± 0.18	96	37.94 ± 6.89	40.62 ± 6.95	<0.001'	2.68 ± 0.21	0.545	0.002	-
<b>Markers of Health</b>													
BMI (kg/m <sup>2</sup> )	130	18.36 ± 3.15	18.07 ± 3.36	<0.001'	-0.12 ± 0.09 <sup>a</sup>	96	18.29 ± 2.42	18.49 ± 2.28	0.004'	-0.03 ± 0.11 <sup>a</sup>	0.575''	0.001	-
BMI SDS	130	0.45 ± 1.14	0.10 ± 1.26	<0.001	-0.30 ± 0.04 <sup>a</sup>	96	0.48 ± 0.92	0.42 ± 0.89	0.085	-0.13 ± 0.05 <sup>a</sup>	0.015''	0.026	Small
SBP SDS	128	-0.18 ± 0.91	-0.41 ± 1.07	0.012	-0.33 ± 0.11 <sup>a</sup>	96	-0.37 ± 1.03	-0.49 ± 0.86	0.283	0.03 ± 0.13 <sup>a</sup>	0.075	0.014	-
DBP SDS	128	0.58 ± 0.78	0.85 ± 0.75	0.001	0.24 ± 0.10 <sup>a</sup>	96	0.72 ± 0.94	0.30 ± 0.90	<0.001	-0.38 ± 0.12 <sup>a</sup>	<0.001	0.050	Small
SBP(mmHg)	128	107.93 ± 8.55	107.02 ± 9.93	0.268	-2.00 ± 1.03 <sup>a</sup>	96	106.71 ± 9.78	106.24 ± 8.00	0.658	1.00 ± 1.25 <sup>a</sup>	0.111	0.011	-
DBP (mmHg)	128	61.29 ± 6.59	63.68 ± 6.44	0.001'	2.08 ± 0.84 <sup>a</sup>	96	62.55 ± 8.12	59.05 ± 7.50	<0.001	-3.08 ± 1.02 <sup>a</sup>	0.001	0.049	Small
HR (bpm)	128	83.16 ± 11.93	78.77 ± 10.78	<0.001'	-1.58 ± 1.21 <sup>a</sup>	96	79.81 ± 11.72	75.33 ± 10.69	0.001'	-9.20 ± 1.57 <sup>a</sup>	0.001''	0.050	Small
550m time (secs)	103	170.76 ± 3.15	156.26 ± 28.12	<0.001'	4.48 ± 4.11 <sup>a</sup>	89	158.87 ± 21.50	153.91 ± 18.33	<0.001'	-8.46 ± 4.59 <sup>a</sup>	0.076	0.017	-
550m time SDS	103	0.51 ± 0.93	0.11 ± 0.95	<0.001	-0.38 ± 0.07 <sup>a</sup>	89	0.22 ± 0.81	0.20 ± 0.72	0.251	-0.03 ± 0.07 <sup>a</sup>	0.004	0.045	Small
<b>FMS</b>													
LOCO (range 0-48)	104	42.10 ± 3.51	45.46 ± 2.61	<0.001'	3.37 ± 0.35	85	42.44 ± 3.17	41.34 ± 3.43	0.007'	-1.09 ± 0.38	<0.001	0.286	Large
OC (range 0-48)	117	38.47 ± 4.27	42.70 ± 2.82	<0.001'	4.23 ± 0.39	87	39.69 ± 3.81	38.41 ± 3.46	0.002	-1.28 ± 0.45	<0.001	0.299	Large
TOTAL FMS (range 0-96)	103	80.44 ± 6.17	88.22 ± 4.10	<0.001'	7.79 ± 0.56	85	82.08 ± 5.16	79.73 ± 5.40	<0.001	-2.35 ± 0.61	<0.001	0.446	Large
PC LOCO (range 0-24)	124	18.07 ± 2.96	18.64 ± 2.50	0.014'	0.57 ± 0.23	90	17.57 ± 2.34	18.21 ± 2.30	0.018'	0.64 ± 0.26	0.818	<0.001	-
PC OC (range 0-24)	124	19.30 ± 2.89	19.49 ± 3.02	0.360'	0.19 ± 0.20	90	19.40 ± 2.76	20.24 ± 2.59	0.001'	0.84 ± 0.23	0.036	0.021	Small
PC TOTAL FMS (range 0-48)	124	37.37 ± 4.85	38.13 ± 4.47	0.025'	0.76 ± 0.33	90	36.97 ± 4.03	38.46 ± 3.83	0.001'	1.49 ± 0.38	0.148	0.010	-

" = Height change was a significant covariate

<sup>a</sup> = Adjusted mean having controlled for height change as a covariate

Group\*Time = group by time interaction effect

\*Effect size only presented if group\*time was significant

'Wilcoxon signed rank test

**SBP** = systolic blood pressure; **DBP** =diastolic blood pressure; **HR** = heart rate; **MVPA** = moderate-to-vigorous PA; **LOCO** = locomotor subset score; **OC** = object-control subset score; **PC LOCO**; perceived locomotor competence; **PC OC** =perceived object-control competence; **PC TOTAL FMS** = perceived FMS competence

**Table 6.4:** Pre- and post-FMS intervention PA data for the intervention and control groups

	Intervention (N=38)			Mean Difference	Control (N=29)			Mean Difference	Group* Time	Partial Eta Squared	Effect Size*
	Pre	Post	p		Pre	Post	p				
Light PA (mins/day)	265.46 ± 49.69	277.36 ± 54.51	0.125	11.90 ± 7.15	257.94 ± 43.77	284.65 ± 53.53	0.001	26.71 ± 8.19	0.178	0.028	-
Moderate PA (mins/day)	38.93 ± 14.17	43.66 ± 14.44	0.023	4.73 ± 2.11	37.33 ± 10.07	50.65 ± 15.93	<0.001	13.32 ± 2.42	0.009	0.099	Med
Vigorous PA (mins/day)	20.70 ± 12.24	22.27 ± 15.06	0.400	1.57 ± 2.08	20.53 ± 11.98	27.21 ± 16.95	0.020	6.69 ± 2.39	0.025	0.075	Med
MVPA (mins/day)	59.63 ± 25.13	65.93 ± 25.42	0.073	6.30 ± 3.72	57.85 ± 20.22	77.86 ± 29.77	<0.001	20.01 ± 4.25	0.018	0.083	Med
Total PA (mins/day)	325.09 ± 60.65	343.29 ± 63.13	0.056	18.20 ± 9.32	315.79 ± 52.57	362.51 ± 74.95	<0.001	46.72 ± 10.66	0.048	0.059	Med
Weekday MVPA (mins/day)	55.73 ± 26.05	66.78 ± 26.87	0.002'	11.05 ± 3.67	57.46 ± 21.50	72.36 ± 28.74	0.007	14.90 ± 4.20	0.492	0.007	-
Weekend MVPA (mins/day)	69.85 ± 31.22	64.94 ± 37.64	0.408	-4.90 ± 6.05	58.33 ± 22.77	92.44 ± 43.68	<0.001	34.10 ± 6.93	<0.001	0.217	Large
% time spent in light PA (mins/day)	34.52 ± 6.22	35.33 ± 6.93	0.387	0.80 ± 0.84	33.79 ± 6.67	36.45 ± 6.83	0.004	2.65 ± 0.73	0.154	0.031	-
% time spent in moderate PA	5.10 ± 1.83	5.46 ± 1.75	0.210	0.67 ± 0.26	4.84 ± 1.39	6.51 ± 1.79	<0.001	1.68 ± 0.30	0.002	0.144	Large
% time spent in vigorous PA	2.98 ± 1.78	2.98 ± 1.91	0.999	0.00 ± 0.26	2.32 ± 1.27	3.17 ± 1.94	0.016	0.84 ± 0.30	0.037	0.065	Med
% time spent in MVPA	8.07 ± 3.36	8.44 ± 3.24	0.450	0.37 ± 0.46	7.16 ± 2.53	9.68 ± 3.24	<0.001	2.52 ± 0.53	0.003	0.128	Med
% time spent in total PA	42.60 ± 7.57	43.77 ± 7.64	0.346	1.17 ± 1.10	40.95 ± 8.14	46.12 ± 9.02	<0.001	5.17 ± 1.26	0.020	0.081	Med
% time spent in weekday MVPA	7.16 ± 3.38	8.27 ± 3.05	0.005	1.11 ± 0.46	7.37 ± 2.84	8.98 ± 3.40	0.017	1.61 ± 0.43	0.474	0.008	-
% time spent in weekend MVPA	9.58 ± 4.44	8.61 ± 4.97	0.259	-0.97 ± 0.87	7.94 ± 3.03	12.50 ± 5.95	<0.001	4.56 ± 1.00	<0.001	0.210	Large

Group\*Time = group by time interaction effect

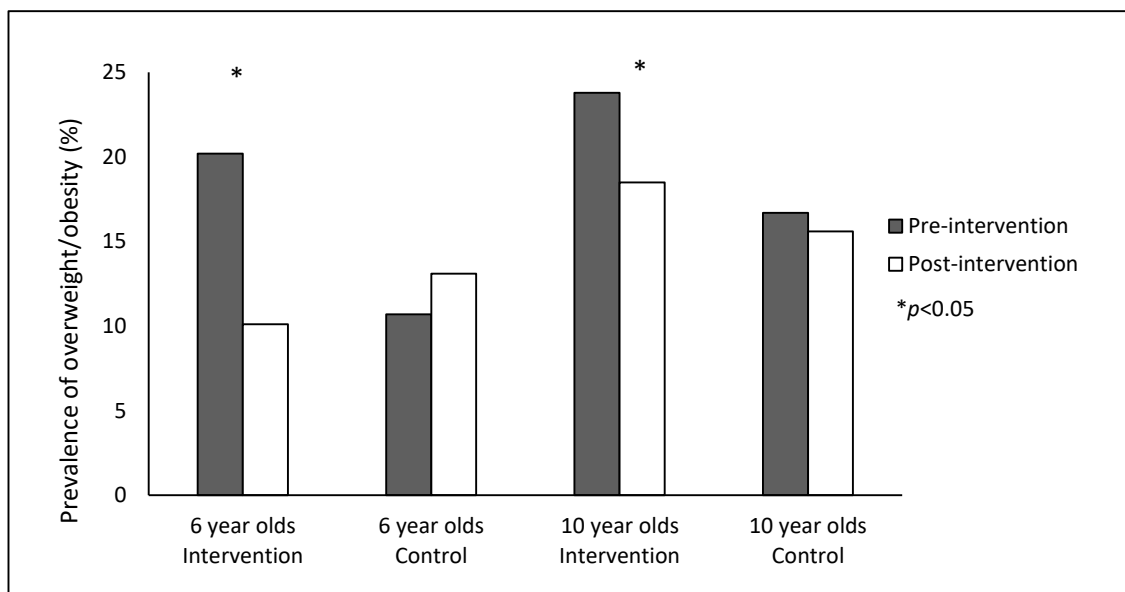
\*Effect size only presented if group\*time was significant

Med = medium effect size

'Wilcoxon signed rank test

**MVPA**=moderate-to-vigorous PA; **total PA**=light PA + MVPA

The prevalence of overweight/obese children among the 6 and 10 year old intervention and control groups at pre- and post-intervention are presented in Figure 6.1. Among the 6 year old cohort, 20.2% of children from the intervention group and 10.7% of children from the control group were overweight/obese pre-intervention. Among the 10 year olds, 23.8% of the intervention group and 16.7% of the control group were overweight/obese pre-intervention. Among both the 6 and 10 year old cohorts, chi-squared tests revealed no significant difference in the proportion of overweight/obese children in the intervention and control groups at either pre- or post-intervention ( $p>0.05$ ). However, among the 6 and 10 year old intervention groups, there were significant decreases in the proportion of overweight/obese children from pre- to post-intervention ( $p<0.05$ ). A 10.8% and 4.6% decrease in the prevalence of overweight/obesity was found among the 6 and 10 year old intervention groups (Figure 6.1), respectively, with no significant pre- to post-intervention difference revealed among the respective control groups ( $p>0.05$ ).



**Figure 6.1:** The proportion of overweight/obese children in the 6 and 10 year old intervention and control groups pre- and post-intervention

The proportion of children who met the WHO's recommendation of 60 minutes MVPA per day, per weekday and per weekend day (i.e. were sufficiently active) are presented in Table 6.5. There was a significant increase in the proportion of children who were sufficiently active on weekdays from pre- to post-intervention among both the

intervention (pre-intervention: 36.8%, post-intervention: 55.3%,  $p < 0.05$ ) and control group (pre-intervention: 37.9%, post-intervention: 65.5%,  $p < 0.05$ ). There were also significant pre- to post-intervention increases among the control in the proportion of children who met the 60 minute daily MVPA recommendation on weekend days (pre-intervention: 44.8%, post-intervention: 79.3%,  $p < 0.01$ ) and daily across the full week (pre-intervention: 41.4%, post-intervention: 75.9%,  $p < 0.01$ ). However, it should be noted that the sample sizes of the respective groups were small (intervention:  $n=38$ , control:  $n=29$ ), which may have influenced the results.

The prevalence of 'high-normal/high' BP among the 6 and 10 year old intervention and control group pre- and post-intervention are presented in Table 6.6. Among 6 year olds, there was no significant difference between the intervention and control group at pre- or post-intervention ( $p > 0.05$ ). There were also no significant pre- to post-intervention differences among the intervention and control group ( $p > 0.05$ ). Among the 10 year olds, there was no significant difference between the intervention and control group at pre-intervention ( $p > 0.05$ ). However, there was a significant decrease in prevalence of 'high-normal/high' BP among the control group ( $p < 0.01$ ) with no concurrent (significant) difference found among the control ( $p > 0.05$ ). As a result, there were a significantly smaller proportion of children from the control group with 'high-normal/high' BP at post-intervention when compared to their counterparts in the intervention group ( $p < 0.01$ ).



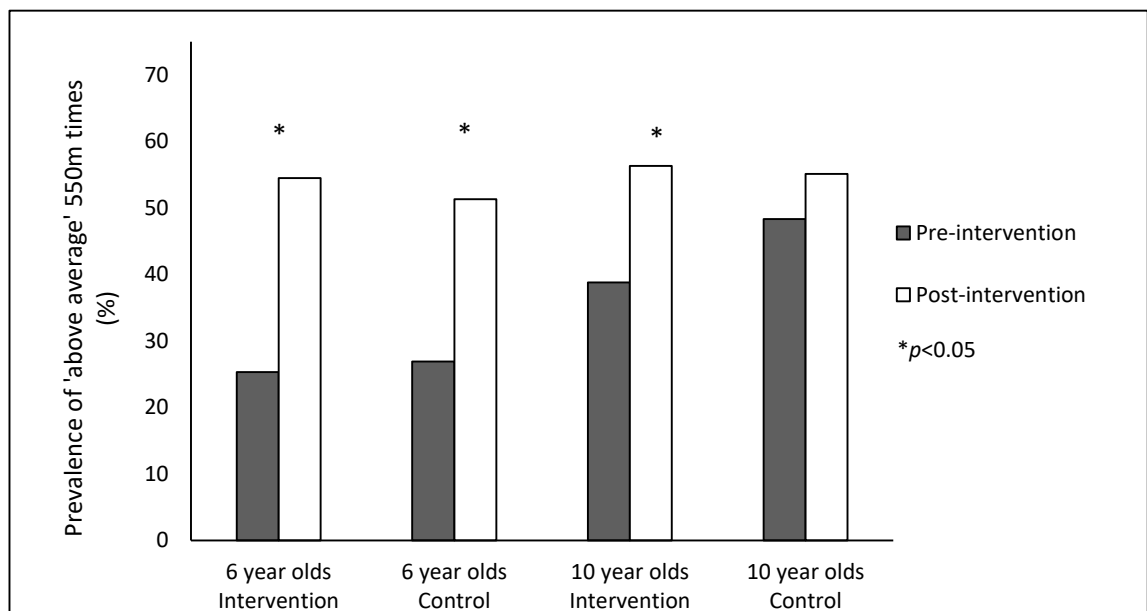
**Table 6.5:** The proportion of ‘sufficiently active’ children in the intervention and control groups pre- and post-intervention

	Intervention			Control			Difference between intervention and control groups	
	Pre	Post	<i>p</i>	Pre	Post	<i>p</i>	Pre	Post
All Days	17/38 (44.7%)	21/38 (55.3%)	0.206	12/29 (41.4%)	22/29 (75.9%)	0.004	0.785	0.084
Weekday	14/38 (36.8%)	21/38 (55.3%)	0.035	11/29 (37.9%)	19/29 (65.5%)	0.011	0.928	0.400
Weekends	22/38 (57.9%)	17/38 (44.7%)	0.197	13/29 (44.8%)	23/29 (79.3%)	0.002	0.292	0.005

**Table 6.6:** The proportion of children with ‘high-normal/high’ BP in the intervention and control groups pre- and post-intervention

	Intervention			Control			Difference between intervention and control groups	
	Pre	Post	<i>p</i>	Pre	Post	<i>p</i>	Pre	Post
<b>6 year olds</b>								
High-Normal/High	20/114 (17.5%)	17/114 (14.9%)	0.590	10/81 (12.3%)	7/81 (8.6%)	0.405	0.421	0.269
<b>10 year olds</b>								
High-Normal/High	30/128 (23.4%)	35/128 (27.3%)	0.411	26/96 (27.1%)	13/96 (13.5%)	0.007	0.537	0.014

The proportion of children from the 6 and 10 year old intervention and control groups who had 'above average' times in the 550m run (based on the age and sex-specific centiles of Rush and Obolonkin (2014) i.e. scored higher than the 50<sup>th</sup> percentile, are presented in Figure 6.2). Among the 6 year old cohort, there was a significant increase in the proportion of children who completed the 550 metres in 'above average' times among both the intervention (pre-intervention: 25.3%, post-intervention: 54.5%,  $p<0.05$ ) and control (pre-intervention: 26.9%, post-intervention: 51.3%,  $p<0.05$ ) groups. Among the 10 year old cohort, there was a significant increase among the intervention group (pre-intervention: 38.8%, post-intervention: 56.3%,  $p<0.05$ ) only, with no significant difference found among the control group (pre-intervention: 48.3%, post-intervention: 55.1%,  $p>0.05$ ).



**Figure 6.2:** The proportion of children in the 6 and 10 year old intervention and control groups who complete the 550m run/walk in an 'above average' time

The proportion of teachers who strongly agreed, agreed, were undecided, disagreed and strongly agreed with each of the of the 5-point Likert scaled statements on the mid-programme questionnaire are presented Table 6.7. Results revealed that the intervention had positive effects on both teachers and children. The majority of teachers noted that as a result of the intervention they were more aware of the importance of PA (95.5%), they were more active (58%) and their knowledge of healthy eating had

improved (71%). Teachers felt that children were more attentive in class following PA sessions (67%), children's fitness levels had improved (88%) and children's eating habits had improved (55%).

**Table 6.7: Teacher responses to the mid-programme questionnaire (N=24)**

		Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	No response
1.	Delivering the physical activity sessions every day for 20 minutes is manageable		16 (67%)	2 (8%)	5 (20%)		1 (4%)
2.	I make every effort to deliver the 20 mins of extra physical activity everyday	4 (16%)	17 (70%)	2 (8%)	1 (4%)		
3.	After I deliver 'Spraoi' my class were more attentive in class than usual	6 (25%)	10 (42%)	8 (30%)			
4.	After I deliver Spraoi my class were more boisterous in class than usual	1 (4%)	5 (20%)	3 (12.5%)	11 (46%)	4 (16%)	
5.	I actively participate in Spraoi activities while the Energizer is delivering to my class	5 (20%)	10 (42%)	5 (20%)	4 (16%)		
6.	I actively participate in Spraoi activities while I deliver Spraoi to my class	7 (29%)	16 (60%)	1 (4%)			
7.	As a result of Project Spraoi I have noticed an improvement in my student's fitness levels	14 (58%)	8 (30%)	2 (8%)			
8.	As a result of Project Spraoi I am more aware of the importance of PA	14 (58%)	9 (37.5%)	1 (4%)			
9.	I am personally more physically active as a result of Project Spraoi	2 (8%)	12 (50%)	6 (25%)	1 (4%)	2 (8%)	1 (4%)
10.	I am a physically active person	6 (25%)	14 (58%)	3 (12.5%)	1 (4%)		
11.	I am confident to deliver FMS activities on my own the days that the Energizer is not there	9 (37.5%)	15 (62.5%)				
12.	I think that the activities delivered by the Energizer are appropriate and easy to manage with my class	19 (79%)	5 (21%)				
13.	As a result of Project Spraoi my knowledge of healthy eating has improved.	6 (25%)	11 (46%)	3 (12.5%)	2 (8%)	1 (4%)	1 (4%)
14.	As a result of Project Spraoi I have noticed an improvement in my student's eating habits	6 (25%)	8 (30%)	8 (30%)	4 (16%)		

Positive themes noted in the mid-programme process evaluation were very similar among the teachers. The most common positive themes that emerged related to the children’s enjoyment of participating in the project, the teachers’ satisfaction with the project, the heightened awareness of the importance of active lifestyles and the enhanced fitness/ability/confidence and also enhanced concentration levels among the children (Table 6.8). Improvements that were suggested at mid-programme included the inclusion of gymnastics support (model lessons/CPD workshops), more healthy eating tips especially to parents/guardians, more activity break ideas for use within limited classroom space and ideas of how to fit PA into the day in addition to teaching the content of their crowded curriculum.

**Table 6.8:** A summary of positive elements of the intervention identified by teachers

<b>Theme of comments</b>	<b>Sample teacher comments</b>
Children’s enjoyment	<i>“Entire class thoroughly enjoy it”</i> <i>“Very fun-kids love it”</i>
Teacher satisfaction	<i>“Project Spraoi has been single-handedly the best thing to happen to this school in my 5 years here”</i> <i>“It’s a fantastic project”</i>
Heightened awareness of importance of healthy active lifestyle	<i>“It really gets the kids more active and more aware of the importance of being active”</i> <i>“Physical activity benefits recognised by boys”</i>
Enhanced fitness/ability/confidence	<i>“Big improvements in the previously less active boys, both physically and confidence wise”</i> <i>“Fitness and healthy eating has dramatically improved”</i>
Enhanced concentration	<i>“The children are definitely more attentive and will concentrate more after physical exercise”</i> <i>“Helps concentration”</i>

The proportion of teachers who strongly agreed, agreed, were undecided, disagreed and strongly agreed with each of the 5-point Likert scaled statements on the end of intervention questionnaire are presented Table 6.9. The process evaluation conducted at the end of the intervention revealed that teachers enjoyed taking part in the intervention (100%), found that the workload was manageable (91%) and would like the intervention to continue (100%). The key role of the Energizer was highlighted in that only 14% of teachers felt that the intervention could continue without an Energizer. However, 78% of teachers agreed/strongly agreed that they would continue delivering the intervention following its conclusion in their school.

**Table 6.9:** Teacher responses to the end of year questionnaire Likert statements (N=22)

		Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	No response
1.	I enjoyed taking part in Project Spraoi this year.	21 (95%)	1 (5%)				
2.	I found the workload involved with Project Spraoi this year manageable	13 (59%)	7 (32%)	1 (5%)	1 (5%)		
3.	I would like Project Spraoi to continue in (School name) next year.	21 (95%)	1 (5%)				
4.	I think that Project Spraoi can continue in (School name) next year without the presence of an Energiser.	1 (5%)	2 (9%)	11 (50%)	7 (32%)	1 (5%)	
5.	I will continue to implement Project Spraoi next year after the intervention has finished	3 (14%)	14 (64%)	4 (18%)			1 (5%)

**Table 6.10:** Teacher responses to the end of year questionnaire questions relating to the delivery of the intervention (N=22)

	Very Good	Good	OK	Poor	Very Poor	No Response
Nutrition Content	9 (41%)	6 (27%)	3 (14%)	1 (5%)	1 (5%)	2 (9%)
PA Content	22 (100%)					
Energizer Capability	22 (100%)					

Some comments that teachers noted on their evaluation of the project were that the intervention was *“a marvellous project to be involved in”*, *“the children loved every second of it”*, the children *“worked better after Spraoi (PA) breaks”* and there was a *“visible difference of fitness”*. One principal participated in this process evaluation of the intervention. Notably, the principal rated all aspects of the intervention, namely the PA content, the nutrition content and the Energizer’s capability with maximum scores. An additional comment noted by teachers were that it would be difficult to keep up the intervention without the Energizer. Improvements suggested included more parental involvement and more nutrition lessons. Teachers’ favourite parts of the intervention included the PA initiatives (especially the Kilometre Challenge), seeing the children enjoy the games/activities/learning new skills and games/PA sessions, trips to the local

university for activities and the daily PA break charts. Barriers identified by the teachers were time constraints due to a crowded curriculum (noted by 16/22, 73% teachers), large class size (noted by 1/22, 5%) and poor behaviour among the class (noted by 1/22, 5% teacher). Facilitators/positive aspects reported included the Energizer's presence, enthusiasm, professionalism, energy and rapport with children (a reference was made to the Energizer by 15/22, 68% teachers), PA breaks throughout the day (noted by 7/22, 32% teachers), PA initiatives (noted by 8/22, 36% teachers), homework manuals (noted by 2/22, 9% teachers).

A considerable level of positive feedback was returned from the write and draw activity and the child interviews. In response to being asked how they felt when it was time for Project Spraoi (i.e. intervention) sessions, all interviewed children (n=8) returned positive comments (The responses that children gave were either *"happy"*, *"excited"*, *"good"* or a combination of these) while 6 out of 8 of the children (75%) said that they would be *'sad'* or *'disappointed'* if Project Spraoi (the intervention) were to finish in their school. Furthermore, when asked what they thought of the activities/games delivered by the Energizer, again all 8 children returned positive comments (The responses returned by the children were *'fun'*, *"I like them"*, *"good"* or an exaggerated version of these comments e.g. *"really fun"*). The interviews revealed that children enjoyed being active while learning. In response to the question *"Would you like if you were able to learn more subjects (English/Irish/maths/etc.) while being active and playing games?"*, all children agreed that this would be a positive development with the following reasons identified:.

- *"Because they are really fun and I'd like to learn a lot more while doing exercise" (Girl aged 7 years)*
- *"I don't like work so I'd like to play games while doing work instead" (Boy aged 7 years)*
- *"Because I would be having fun while learning" (Boy aged 8 years)*

- *“Because it would be more fun than just sitting down writing”  
(Boy aged 10 years)*
- *“Because it would be easier to do them because you’d forget you were doing work” (Boy aged 10 years)*

## **6.5 Discussion**

The FMS-based intervention revealed group by time interaction effects in favour of the intervention i.e. there were significantly greater improvements in the intervention group compared to the control group from pre- to post-intervention, for all FMS variables i.e. LOCO, OC and TOTAL FMS (large effect sizes) and BMI SDS (small to medium effect sizes) among both 6 and 10 year old cohorts. There were also group by time interaction effects in favour of the intervention for BMI among 6 year olds (small effect size) and heart rate and 550m time SDS (small effect sizes) among the 10 year old cohort. Furthermore, there was a significant decrease in the proportion of children in the 6 and 10 year old intervention groups categorised as ‘overweight/obese’ following the intervention (with no difference in the prevalence of overweight/obesity among the control group). There was also an increase in the proportion of children from the 6 and 10 year old intervention groups achieving above average 550m times at post-intervention (with only significant improvements among the control group found among 6 year olds).

The intervention effects for FMS highlight the positive effect school-based FMS interventions can have on children’s FMS proficiency and support findings of Tompsett et al. (2017), Logan et al. (2011) and Morgan et al. (2013) who reported that FMS interventions can positively impact on the FMS levels of children. Similar to Morgan et al. (2013), the current study revealed a large effect size for FMS proficiency among both 6 and 10 year olds. Findings from the current study support those of Mitchell et al. (2013) who found significant increases in the proportion of children who demonstrated mastery (i.e. could correctly perform all components of the skills) in all 12 skills assessed following a 6 week Project Energize intervention (that involved the support and



mentorship of classroom teachers for the delivery of FMS based teaching during their PE and fitness classes) ( $p < 0.01$ ). While significant improvements in FMS were reported among children involved in the intervention, the lack of a control group in the study design should be noted.

In contrast to the current study, Cohen, Morgan, Plotnikoff, Callister, et al. (2015), who following 6-months (at mid-program) of the SCORES 12-month multi-component PA and FMS intervention, found no significant difference between the intervention and control groups from pre- to post-intervention for locomotor, object-control proficiency or total FMS among Australian primary school children ( $N=460$ , mean age:  $8.5 \pm 0.6$  years) ( $p > 0.05$ ). However, they did find that the intervention improved significantly more than the control from pre- to post-intervention for total FMS score (as well as PA and CRF) at the end of the intervention i.e. at 12 months ( $p < 0.05$ ). These findings suggest that longer interventions may produce greater improvements in FMS (and markers of health). The current intervention which was carried out over a 26 week period involved approximately 100 minutes of instruction time for each FMS. The Department of Education Victoria (1996) recommend 240-600 minutes of instruction for the mastery of each FMS and so an intervention of longer duration may have an even greater effect on children's FMS proficiency than the current intervention. Furthermore, it has been suggested that intervention duration is positively associated with sustained PA impacts (Lai et al., 2014). In a systematic review of follow-up studies that assessed the sustained impact of school-based interventions that focused on PA, fitness or FMS, it was found that the interventions in eight of the ten studies that had a sustained impact for PA were greater than one year in duration while all three that had no sustained impact were shorter than one year in duration (Lai et al., 2014).

The effect of the intervention on BMI (small effect size for 6 year olds) and BMI SDS (medium and small effect sizes for 6 and 10 year olds, respectively) contrast findings from a systematic review by Tompsett et al. (2017) who reported that FMS interventions have little impact on BMI, weight or BMI z-score. In the review, Tompsett et al. (2017) found that only four of nine (44%) FMS interventions that were evaluated in terms of BMI, weight or BMI z-score, revealed significant positive effects. Furthermore, the

positive effects of three of four of these interventions that found positive effects were postulated to have been largely attributed to the nutritional aspects (e.g. calorie restriction, nutrition education) of the multi-component interventions from which they resulted. The one study which did not include a nutritional focus but found a positive effect on BMI, however, did not find concurrent intervention effects for FMS proficiency. Cliff et al. (2012) suggest that weight loss does not occur in the short-term from FMS intervention but that the improved FMS proficiency that occurs may enhance the movement capabilities necessary for regular and habitual PA participation, and thus promote weight loss in the long-term. However, findings from the current study found intervention effects for BMI (among 6 year olds) and BMI SDS (among 6 and 10 year olds) which highlights that FMS interventions may positively affect adiposity. The Energizer represented and promoted healthy living as a whole (both PA and healthy eating) and so both children's PA and eating habits may have improved. Two nutrition lessons had been delivered to children during the PA intervention (the previous year). This may have influenced children's subsequent eating habits and consequently contributed to reductions in BMI. One of the intervention schools developed a new healthy eating policy and selected an active school committee during the FMS intervention. These health-promoting strategies may also have contributed to the positive adiposity-related findings.

The CRF levels (550m time SDS) of the 10 year old intervention group improved significantly more over time than that of the control group ( $p < 0.01$ , small effect size). Significant increases in the prevalence of above average 550m times were also found among the 6 and 10 year old intervention groups ( $p < 0.05$ ), while significant increases among the control group were found among the 6 year olds ( $p < 0.05$ ) only. CRF improvements have also been previously found by Cohen, Morgan, Plotnikoff, Callister, et al., (2015) among children from low-income communities following a 12 month multicomponent FMS and PA intervention. A systematic review of the effect of FMS interventions on health outcomes by Tompsett et al. (2017) also found that 9 of 11 FMS-based intervention studies that assessed CRF resulted in improvements, further highlighting the positive effect that FMS interventions may have on CRF among children. Children's CRF may have improved as a result of their improved FMS proficiency (as FMS

proficiency is positively associated with participation in PA (Robinson et al., 2015) and PA is positively related to CRF (Ara et al., 2004; Karppanen, Ahonen, Tammelin, Vanhala & Korpelainen, 2012). Furthermore, children’s improved FMS proficiency may have facilitated children’s participation in higher PA intensities than before (Fairclough & Stratton, 2006), which contributes to CRF improvements (Swain & Franklin, 2002). Furthermore, engaging in higher PA intensities requires higher energy expenditure (Ainsworth et al., 1993) which may explain the improvement in BMI SDS. In addition to the group by time interaction effect for CRF (550m SDS) among the 10 year old cohort, there was also a group by time interaction effect for heart rate. CRF is inversely related to resting heart rate (Quan et al., 2014; Silva, de Lima & Tremblay, 2018) and so the improvement in children’s resting heart rate is likely due to their improvement in CRF.

In contrast to the findings from the SCORES (FMS and PA) intervention (Cohen, Morgan, Plotnikoff, Callister, et al., 2015), the PA levels of the intervention group did not improve significantly more over time than those of the control group. In fact, the control group improved significantly more than the intervention group over time for all PA variables except light PA and weekday MVPA, in which there were no significant differences between the intervention and control. These findings may have been due to the different dates and conditions over which intervention and control PA data were collected (Table 6.7). The pre-intervention control data were collected during the last two weeks of November when the average daylight hours per day was 8.5 hours and average temperature was 7.5°C. Post-intervention data were collected in May when average daylight hours per day was 15.6 hours and average temperature was 13.4°C. In contrast, intervention pre-intervention data were collected during the last week of September and first two weeks of October when the average daylight hours per day was 11.4 hours and average temperature was 11.1°C. The intervention group’s post-intervention PA data were collected in June when the average daylight hours per day was 16.7 hours and the average temperature was 13.8°C.

**Table 6.11:** Average daylight hours and temperature during PA data collection

	Average daylight hours (hours/day)			Temperature (°C)		
	Pre	Post	Difference	Pre	Post	Difference
Intervention	11.4	16.7	5.3 (46.5%)	11.1	13.8	2.7 (24.3%)
Control	8.5	15.6	7.1 (83.5%)	7.5	13.4	5.9 (78.6%)

It is likely that the control children's pre-intervention PA data was understated given the smaller amount of daylight hours and colder temperatures relative to what they may have been if collected at the same time as the intervention group's pre-intervention data collection time. Furthermore, control children's PA space/locations (such as grass parks/fields/gardens) may have been limited in late November but may not have been in September/October, which may have also led to lower PA levels (compared to what they may have been in September/October).

There were no significant improvements in PA as a result of the current intervention. However, studies have reported a positive relationship between childhood FMS and adolescent PA (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009c; Jaakkola, Yli-Piipari, Huotari, Watt, & Liukkonen, 2015), childhood FMS and adolescent CRF (Barnett, van Beurden, et al., 2008) and also childhood FMS and adult PA (Lloyd, Saunders, Bremer, & Tremblay, 2014), suggesting that improvements in FMS may positively affect markers of health later in life (through continued or improved engagement in PA). Stodden et al. (2008) proposed that children with higher actual FMS competence will have higher perceived competence and thus maintain participation in PA and sport while those with relatively poor FMS competence will have lower perceptions of their competence and consequently choose to discontinue or reduce their participation levels in PA and sport. These suggestions provide support for the implementation of FMS interventions as opposed to general PA interventions, as the development of FMS may lead to long-term PA and health. Young children tend to have inflated perceptions of their actual FMS competence (De Meester et al., 2016) and thus are likely to persist with physical activities irrespective of the actual FMS competence. Therefore, variations in young children's PA levels may not necessarily depend on their actual FMS levels. However, actual FMS levels may become more important when children do become able to accurately assess their actual FMS competence (approximately at the age of 11 or 12 years (Rudisill, Mahar, & Meaney, 1993), just before the transition from primary to secondary school and adolescence, both of which have been highlighted as critical times during which PA behaviours may change dramatically (Crane & Temple, 2015; Hills, King, & Armstrong, 2007). Therefore, it is important that FMS interventions such as that in the current study that can positively impact children's FMS and markers of health, should

be delivered during the primary school years. Research assessing the long-term effects of FMS interventions on markers of health (such as BMI, PA and CRF) i.e. research that investigates if FMS improvements achieved during the intervention translate to improved PA and CRF later in life, are warranted.

Although there was no significant improvement in weekend MVPA among the intervention group from pre- to post-intervention, there was an increase in weekday MVPA (in addition to improvements in FMS) among the intervention group. However, this improvement was not significantly different from that of the control group ( $p>0.05$ ). To enhance PA levels (as well as FMS proficiency), extra PA sessions (in addition to FMS-based lessons and classroom activity breaks) may be necessary. Kemper (2000) outlined that a minimum of one PE lesson per day (that focuses on FMS development and motivating children to be active during their free time) is necessary to improve PA levels. Future research should investigate such an intervention.

Findings from the current study that found no significant difference between the intervention and control groups over time for perceived FMS competence (despite improvements in actual FMS competence) are similar to those of the SCORES intervention who found improvements in actual FMS but not perceived FMS following their 12-month intervention among children from low-income communities. A possible explanation for these findings is that children cannot accurately assess their actual FMS competence until approximately 11 or 12 years of age (Rudisill et al., 1993). However, in contrast, Morano et al. (2014) following a 32-week FMS-based intervention among a sample (N=41) of 8-10 year old obese children in Italy, found significant improvements in actual FMS scores and perceived physical ability scores (in addition to self-reported PA) at post-intervention. However, it should be noted that the sample size was limited (N=41), PA was self-reported, a non-aligned measure of perceived competence (the Perceived Physical Ability Scale for Children (Colella, Morano, Bortoli, & Robazza, 2008) was used to evaluate perceptions of competence and there was no control group used in the study. Key differences in the study by Morano et al. (2014) which may have had a positive impact on perceived competence levels were the intervention's longer duration (32 weeks versus 26 weeks), the larger amount of contact time between the FMS

specialists and children per week (2-3 hours per week versus 1 hour), the inclusion of a 25-minute period of 'individualised' skills training (in groups of 1-4) and the delivery of a weekly 40-minute session of behavioural training to children and their families to promote voluntary participation in PA.

It is interesting to note that among the 10 year old cohort, children's actual locomotor score was superior to their actual object-control score but yet their perceived object-control score was higher than their perceived locomotor score. This may be because 10 year old children tend to underestimate their locomotor proficiency and overestimate their object-control competence (Bolger et al., in press). This tendency to underestimate locomotor skill competence may be due to children's belief that others have superior ability in achieving the outcome of a skill performance (Barnett, Salmon, Timperio, Lubans & Ridgers, 2017) (e.g. are faster, can jump further) or children's reluctance to report their true perceptions for fear of boasting or overestimating in the presence of the assessor (Bolger et al., in press). Children's overestimation of object-control competence may again be due to children's tendency to base their perception of competence on the outcome of the skill performance (e.g. successful contact with the ball for the kick, strike and dribble, release of the ball for the throw) rather than assessing the quality of the technique they used to produce the skill outcome (Barnett et al., 2017).

Overall, the findings of the current study are similar to those reported by Jarani et al. (2016), who following a 5-month FMS based intervention among 378 first-grade (mean age: 6.8 years) and 389 fourth-grade (mean age: 9.8 years) children from Albania, reported significant improvements among the intervention groups in FMS proficiency and CRF, relative to the control ( $p < 0.01$ ), with no concurrent improvement in PA ( $p > 0.01$ ). The intervention was similar to the current intervention in that it consisted of two sessions per week. However, it should be noted that these sessions were longer in duration (45 minutes vs. 25 minutes).

This positive feedback from the process evaluation was noteworthy and provide further support for the implementation of a school-based FMS intervention such as that delivered in this research. Support for the inclusion of many of the intervention

components (e.g. the Energizer, PA breaks, PA initiatives, FMS homework) was provided. The presence of an Energizer was highlighted as one of the most important components as 68% teachers referred to the Energizer as a facilitator of the intervention. Furthermore, only 14% of teachers felt that the intervention could continue without the presence of an Energizer. These findings support those of Kriemler et al. (2011) who reported that the most effective school-based interventions were specialist led and suggest that future school-based interventions should be specialist-led.

### Strengths and Limitations

Strengths of the current intervention were its evidence based design. The intervention was multi-component in nature, specialist-led and included a home-based aspect (the homework manuals), factors which have been found to be associated with previous effective FMS interventions (Tompsett et al., 2017).

While the intervention included the family through FMS homework, future interventions should also consider the use of an interactive resource such as that developed during this research (Appendix B). The resource includes short video demonstrations of a child correctly performing each FMS, in addition to simple, clear teaching cues and should be considered as the combination of instruction and demonstration is generally the most effective for the presentation of practice information (Edwards, 2010). Such a resource could then be made available to teachers and parents via an intervention website, and could be used in conjunction with the homework manuals, to help facilitate and encourage children to use correct technique of FMS during the completion of the FMS homework. Parent evenings that involve the delivery of information relating to FMS and PA (and possibly healthy eating), should be considered to further educate parents and encourage them to facilitate their child's optimal skill and physical development and health status. These parent evening would also give parents the opportunity to interact with the Energizer and ask the Energizer any questions they may have in relation to FMS, PA or healthy eating. Separate information evening/workshops to teach parents the correct FMS technique should be delivered so that parents can assist children in the completion of the FMS homework and possibly even provide appropriate feedback to their children on their performance of their FMS. Weekly newsletters should also be

considered as parents of children who participated in the SCORES FMS and PA intervention (Cohen, Morgan, Plotnikoff, Callister, et al., 2015) reported that the newsletters distributed to them as part of the intervention provided them with useful information about the promotion of PA in children.

While some interventions have been evaluated, based on pre- to post-intervention differences, with no control group (Cliff et al., 2007; Mitchell et al., 2013), this study was a controlled trial. However, it must be noted that the control school was different to the intervention schools, in that the setting was a rural mixed school, with vast PA facilities (a large grass field, an astro-turf pitch, a large yard, a large indoor sports hall and a small sports hall) and equipment, compared to the urban, single sex intervention schools, with limited yard space and a small, shared hall. Furthermore, the control school were scheduled for their 1 hour of PE, as recommended by the DES, while the interventions schools were only scheduled for 55 (boys) and 50 minutes (girls) per week, respectively.

While a strength of the current study was the use of an objective measure of PA, a limitation that must be noted was the sample size from which valid PA data was collected. First of all, only a subsample of children received accelerometers, due to limited accelerometer availability. Furthermore, only 75 of the 247 (30.4%) that received the accelerometers provided valid pre- and post-intervention data (even when the less stringent wear time criteria of 3 days of at least 10 hours of wear was applied). This is much lower than the 79.5%-81.4% wear time compliance rate found by Troiano et al. (2008) among 6-11 year old American children (for 3 or more days with 10 or more hours of wear time). In contrast to the current study, however, data was collected at only one time point in the study of Troiano et al. (2008). While the researcher distributed information sheets (Appendix E. 4) and SMS messages to parents/guardians of children who received accelerometers in an attempt to maximise compliance (Belton et al., 2013), competitions that award children (with a daytrip) who reach a specific wear time criterion could further promote compliance (McCann et al., 2016). Alternatively, wrist-worn accelerometers could be used as wrist-worn accelerometers have been found to result in higher compliance when compared to hip-worn monitors (Fairclough et al., 2016). Anecdotal evidence suggests that some children (despite instructions to wear the



accelerometer at all times) removed the accelerometer during participation in sporting activities due to discomfort and so future research should consider using a combination of PA diaries and accelerometers in the collection of PA data. Another limitation resulting from the low accelerometer availability, as previously noted, was the collection of PA data from the intervention and control groups during different time periods. As this is likely to have led to an underestimation of control children's pre-intervention PA levels. Future studies should collect PA data from intervention and control groups during the same time period.

## **6.6 Conclusion**

The current study revealed that a multi-component FMS-based intervention can result in significant motor skill acquisition improvements, among a cohort of Irish primary school children. While the current intervention was carried out using a pre-post intervention design, future research (which will be carried out by other members of the Project Sproai Research Team) will examine the effectiveness of the intervention using a pre-post-follow-up design. Such an examination will assess the long-term effects of the intervention (Roberts & Ilardi, 2003). There were no intervention effects for BP, PA or perceived competence. However, the positive intervention effects for FMS, CRF and BMI are noteworthy given the poor FMS (Bolger et al., 2017; Farmer et al., 2017), CRF (Hudson et al., 2015; Woods et al., 2010;) and overweight/obesity levels (Bel-Serrat et al., 2017) observed among Irish primary school-aged children. The FMS improvements are particularly noteworthy given the large effect sizes for total FMS that were found among both 6 and 10 year old cohorts. Findings that revealed improvements in both locomotor and object-control skills are also positive suggesting that both types of skills can be enhanced following the delivery of an intervention such as that in the current study. In an attempt to improve PA, in addition to FMS, CRF and BMI (as was found in this study), children should engage in daily PE lessons. Two to three of such lessons per week should be devoted to FMS development and the remainder to activities that facilitate MVPA and/or encourage children to be active in their free time.

**Chapter 7:**  
**Discussion, conclusion and recommendations for  
future research**

## 7.1 Introduction

There were three core aims associated with this research project. The first was to evaluate the FMS proficiency and markers of health of a cohort of Irish primary school children, and examine the relationship that exists between FMS and markers of health among this cohort. The second was to deliver a PA intervention to primary school children from two intervention schools and evaluate its effectiveness on children's FMS proficiency and markers of health. The third aim of the research was to design and implement a tailored FMS intervention for primary school children, and evaluate its effectiveness on the FMS proficiency and markers of health of a cohort of Irish primary school children. While the results of each of these studies have been presented in detail in Chapters 4-6, this chapter serves to summarise the overarching findings of the research. A number of recommendations relating to the development of FMS and the improvement of markers of health of Irish primary school children are also provided.

## 7.2 FMS and Markers of Health

The current research found that FMS proficiency was positively associated with CRF with a negative correlation found between FMS and 550m run time SDS among 6 year olds ( $r=-.286, p<0.01$ ) and 10 year olds ( $r=-.330, p<0.01$ ) (Chapter 4). These findings suggest that children with higher FMS completed the 550m track in less time and therefore had higher levels of CRF. Further analysis of this relationship (via stepwise multiple linear regression) revealed that FMS explained 15.9% and 20.5% of the variance in CRF among 6 and 10 year olds, respectively. Interestingly, no one particular skill was found to be a significant predictor of CRF among *both age groups* i.e. 6 year olds and 10 year olds, however it was found that a large number of the selected FMS significantly predict CRF among children (The kick, dribble, hop were significant predictors of CRF among 6 year olds while the roll, gallop and jump were significant predictors of CRF among 10 year olds). The current research also found that FMS proficiency was positively associated with light PA ( $r=.413, p<0.05$ ) and total PA ( $r=.351, p<0.05$ ) levels, suggesting that those with higher FMS proficiency engage in more PA than their less skilled counterparts. It is

likely that children with higher FMS levels participate in more organised sport than their less skilled counterparts. Organised sporting activities provide children with the opportunity to practice FMS and enhance their CRF. Additionally, it also gives them the opportunity to receive instruction and feedback from coaches. Research carried out by Field and Temple (2016) among 400 children (mean age: 9.5 years) found that locomotor and object-control proficiency was positively correlated with participation in team sports among boys ( $r=.210$  and  $r=.255$ ,  $p<0.05$ ) and organised gymnastics among girls ( $r=.333$ ,  $p<0.01$ ). Furthermore, Temple (2016) who investigated the relationship between FMS and organised sport among a cohort of 74 kindergarten children (mean age: 5.92 years), found a significant moderate correlation between object-control proficiency and organised sport among boys ( $r=.400$ ,  $p<0.05$ ). Among Irish children, O'Connor et al. (2018) reported a higher level of FMS among a cohort of Irish children who play Gaelic games ( $N=63$ , mean age:  $9.9 \pm 1.3$  years) than had been previously reported by Bolger et al. (2017) who assessed the FMS levels of a sample of children from the general population, suggesting that FMS proficiency may be associated with organised sport among children.

Reviews by Lubans et al. (2010) and Robinson et al. (2015) indicate that FMS are positively associated with health benefits among children and adolescents, including PA, CRF and adiposity level. While these findings were drawn from studies involving both children and adolescents, the majority of which were from the USA or Australia, the current research found some similar results among a cohort of Irish children. The findings of the current study also support those of Farmer et al. (2017) who found that among a cohort of Irish girls ( $N=160$ , mean age:  $10.69 \pm 1.40$  years), locomotor proficiency differed significantly depending on girls' activity levels, with higher activity categories associated with higher locomotor skill proficiency levels. Furthermore, it was found that FMS explained 9.7% and 14.4% of the variance in light PA and total PA, respectively. Woods et al. (2010) reported that a 'lack of competence' was identified by approximately 15 and 20% of primary school boys and girls, and 35 and 25% of post-primary school boys and girls, as a reason for not participating in sport/PA. These findings suggest that perceived competence may be a predictor of childhood PA levels

and thus the development of actual and perceived FMS among children may have the potential to prevent or reduce the incidence of dropout in sport in later years.

### **7.3 The PA Intervention**

The evaluation of the PA intervention is of significant importance due to its positive impact on the 6 and 10 year old children's adiposity levels and the 10 year old children's CRF. It also provides data that relates to the current FMS proficiency levels and markers of health among Irish primary school children. Data collected prior to the PA intervention revealed that the FMS proficiency of a cohort of Irish primary school children was low relative to the normative sample of the TGMD-2 manual (Bolger et al., 2017), highlighting that interventions to improve FMS as well as markers of health are warranted. The evaluation of the PA intervention (Chapter 5) found positive intervention effects for WC SDS among both 6 and 10 year olds, and CRF among the 10 year olds (550m time SDS and the proportion of children achieving above average 550m times). However, no intervention effects were found for FMS or any of the other markers of health assessed (BMI, BP, heart rate, PA), suggesting that modifications to the intervention were necessary. The limited positive effects of the PA intervention may have been due to the fact that the Energizer-led sessions which were intended to be additional to PE actually replaced PE class (a period during which children already engage in PA) because of the time constraints of the overcrowded primary school curriculum. (The Irish primary school curriculum consists of a large number of subjects (12 in total) (NCCA, 2018). However, the time devoted to each of these is not equal with most of the emphasis in schools placed on literacy and numeracy i.e. English and maths (Department of Education & Skills, 2011). This is due to the pressures placed on teachers to achieve high standardised test scores (English and maths) and also requests from the Department of Education and Skills asking schools to increase the time devoted to these core academic subjects (Department of Education & Skills, 2011). Furthermore, despite the provision of a professional development workshop, printed PA resources and encouragement to allow children to engage in at least 20 minutes of MVPA every day, anecdotal evidence from regular visits to the school and interaction with the class

teachers suggests that teachers did not facilitate this daily 20 minutes MVPA. Analysis of the process evaluation supporting this research revealed that teachers felt this was largely due to the time constraints of a crowded curriculum. Given the limitation of the absence of teacher engagement monitoring for the PA intervention, its inclusion was added to the methods for the evaluation of the motor skill intervention. One of the key learnings from this intervention was that a greater effort to involve parents and teachers in the 2<sup>nd</sup> intervention (FMS-based) was warranted. Previous research highlights that intervention approaches most consistently associated with positive effects include parents and teachers (Morgan et al., 2013; Mura et al., 2015; Tompsett et al., 2017). While efforts were made to involve both groups (in particular teachers), it was somewhat difficult to engage them. Future interventions should explore ways to incorporate these groups into their intervention design with greater levels of consistency and intent.

#### **7.4 The FMS Intervention**

The current research resulted in the design, development and delivery of Ireland's first primary school-based FMS intervention. FMS-based intervention materials developed during this process included resources that can be used or adapted in future FMS and/or PA interventions. Such resources include FMS-based lesson plans (Appendix D.1), FMS-based activity break charts (Appendix D.5), FMS homework manuals (Appendix D.3), FMS teacher manuals (Appendix D.4) and various PA initiative resources (Appendices C.2, D.6-D.9). An interactive FMS teaching tool (Appendix B) was also developed during the research. This digital resource that was funded by the Teaching and Learning Unit at Cork Institute of Technology has great potential to assist teachers, coaches and parents to develop the FMS of children. The resource contains videos of each of the 12 skills of the TGMD-2. The videos presented demonstrate correct performance and also identify key teaching cues for each of the skills. Intervention results revealed positive effects for all FMS variables (LOCO, OC and TOTAL FMS). The 'Fundamental motor skills: A manual for classroom teachers' resource developed by the Department of Education Victoria (1996) outlines that 240-600 minutes of instruction are required to become proficient

at one FMS. Given that children in this intervention received only approximately 100 minutes of instruction, i.e. 17-42% of the recommended time, an intervention of greater duration may produce even greater improvements in FMS proficiency. Due to the worryingly low levels of FMS among Irish children and the long term implications associated with low FMS (reduced PA levels, decreased CRF and a higher prevalence of overweight/obesity), the findings from the current research are very encouraging. It is recommended that these results be adopted by teacher training colleges, teacher CPD (continuing professional development) workshops and even sports governing bodies (who deliver underage coaching courses/workshops to their current/future members).

The FMS intervention carried out in the current research (Chapter 6) was effective at concurrently improving FMS, CRF and reducing levels of overweight/obesity. However, there were no improvements in PA levels following the intervention. Van Beurden et al. (2003) found similar results (significant FMS improvements ( $p < 0.01$ ) but no difference in PA levels ( $p > 0.05$ )) among 7-10 year old Australian children and as a result recommended increasing the number of PE lessons per week. Furthermore, Kemper (2000) recommended the delivery of daily PE lessons to improve PA levels among children. Research carried out by Marshall and Bouffard (1997) demonstrated that children from schools that engage in quality *daily* physical education (QDPE schools) were fitter and more competent at FMS than children in non-QDPE schools, which consolidates the recommendation of the delivery of quality daily physical education lessons. The current research highlights the need for a greater provision of FMS and PA breaks among Irish schools. With FMS in childhood positively associated with PA and fitness in later years (Barnett, Morgan, et al., 2008; Barnett, van Beurden, et al., 2008; Lloyd et al., 2014), FMS improvements observed in the current research may not immediately translate to health but may do so in later years with continued or increased participation in PA and/or sport.

While the FMS-based sessions during this intervention, similar to the PA intervention, replaced the regular PE class inadvertently, additional components such as the FMS activity breaks encouraged teachers to allow children to engage in 20 minutes structured FMS activities daily. The PA charts that were used to encourage PA breaks

during the school day were also designed to collect data relating to teacher's engagement in the delivery of PA opportunities to the children in their class. These charts revealed that teachers (N=27) facilitated children's engagement in PA for on average 13.5 additional minutes per day during the intervention. Given the crowded Irish primary school curriculum (Department of Education and Science, 1999), it is very encouraging that the intervention resulted in the devotion of extra time to PA and FMS development. As a consequence of the significant positive impact that the FMS intervention had on the FMS, adiposity and CRF levels of children, policy makers should consider adopting it in primary schools across the nation. The implementation of the intervention in primary schools across the country has the potential to not only enhance the health of Irish children (and future adolescents and adults), but also to reduce the substantial economic burden of hypokinetic diseases such as obesity. A recent report issued by Safefood Ireland outlined that a 1 and 5% reduction in population mean childhood BMI in Ireland would result in savings of €270 million and €1.1 billion, respectively (Perry et al., 2017). Given that the current intervention resulted in reductions in BMI of 4.8% among 6 year olds and 1.6% among 10 year olds, its implementation across the country has the potential to be of major economic benefit.

The findings from the current interventions add to previous evidence that supports the use of the socio-ecological model for health as a framework for interventions (Cohen et al., 2015; Simon et al., 2014; Tehrani, Majlessi, Shojaeizadeh, Sadeghi, & Kabootarkhani, 2016;). The multi-component nature of its approach which targeted intrapersonal, interpersonal, organisation, community and policy factors allowed the messages of the intervention to be delivered and reinforced by numerous different individuals (e.g. the Energizer, Active Agents, teachers, principals, parents) and in many different settings (e.g. at school, at home, at the local university).

While the intervention attempted to involve parents (via the FMS homework and information sheets), no feedback was received from parents. Furthermore, at the end of the PA intervention, parents were invited to request the test results of their children. However, no parents availed of this invitation. Future interventions should attempt to identify barriers for parental involvement in the intervention and



subsequently address these issues to increase parental involvement. While numerous methods have been used in previous interventions to increase parental involvement (e.g. parent information evenings, negative consequences for undesired behaviour, homework activities, economic incentives), interactive and practical initiatives that involve both children and parents such as food tasting or cycling tours have been found to be the best (Van Lippevelde et al., 2011).

#### **7.4.1 Practical Implications**

While an intervention such as this are effective at improving FMS, the feasibility of such a programme (i.e. the cost of employing an Energizer in a school) may not be feasible in Ireland. In an effort to overcome this issue, other potential ways to improve the quality and quantity of PA/PE delivered by classroom teachers should be explored. The following section discusses potential mechanisms to achieve this.

First of all, the author recommends that weekly PE time for Irish primary school children should be increased. Currently, schools are 'recommended' to deliver 1 hour of PE per week (Department of Education and Science, 1999). However, a study among Irish primary schools (N=53) revealed that not all schools are timetabled for, or receive this (Woods et al., 2010). One such school was part of the current research. In fact, only 35% of Irish primary schools were timetabled for the recommended one hour of PE per week (Woods et al., 2010). While the current research encouraged teachers to allow children to engage in at least 20 minutes MVPA every day, process evaluation results (Chapter 5) found that 'time constraints' due to a crowded curriculum was identified as the primary barrier to achieving this. In order to increase the PA levels of primary school children in Ireland, daily 30 minute PE lessons should be included as a mandatory component of the Irish primary school curriculum. Inevitably, this would require a revision of the amount of time allocated to each subject in the current primary school curriculum or an extension to the primary school day. While these would be significant adaptations to the current primary school structure, it is likely that the economic benefits that result would exceed the costs incurred as recent figures highlight that total lifetime costs attributable to childhood overweight/obesity in Ireland amount to over €4 billion

(€16,036 per person) (Perry et al., 2017). PA may also be incorporated into academic lessons (Martin & Murtagh, 2015). However, the sustainability of this strategy alone is questionable as it would place an increased workload on teachers or alternatively the design and development of an extensive bank of active lesson plans for each class group. Children who engage in 30 minutes of quality daily PE (QDPE schools) have been found to be more competent at FMS and fitter than their counterparts from non-QDPE schools who engaged in PE on two to three occasions during the week (Marshall & Bouffard, 1997). A survey by Safefood Ireland supports increased PE provision in schools and notably found that 90% of parents believed that children should receive 30 minutes of PE every day (Courtney, 2014). Furthermore, the Irish Primary Physical Education Association has recommended a 150 minutes (30 minutes per day) of the primary school week to be devoted to PE (Looney, 2017). There are a multitude of both short term and long term benefits of increased quantity and quality PE sessions. For example, women who received daily primary school PE during their childhood years have been found to engage in more self-reported PA as adults than their counterparts who engaged in 40 minutes PE per week during primary school, while there was reduced risk of becoming a smoker among men who engaged in daily PE during primary school (Trudeau, et al. 1999). A study conducted among 7-9 year old girls has also found that daily PE enhances bone mineral content and areal bone mineral density (Valdimarsson, Linden, Johnell, Gardsell, & Karlsson, 2006).

The quality of PE lessons delivered by classroom teachers has previously been highlighted as an area of concern (Morgan & Hansen, 2008) and efforts should be made to increase the quality of PE provision. It has been reported that primary school PE often involves large-sided games resulting in a very limited focus given to the development of movement skills, the provision of appropriate feedback and the promotion of PA (Morgan & Hansen, 2008). Inadequate time spent on PE in teacher training colleges has been identified as a barrier to the teaching of quality PE (Morgan & Hansen, 2008; Sofu & Asola, 2016). In Ireland, pre-service teachers are required to complete just two PE-based modules (Dublin City University, 2018; Mary Immaculate College, 2018). Furthermore, these modules are shared with other subjects, for example 'Drama and Physical Education' (Dublin City University, 2018) and 'Social, Personal, Health and

Physical Education' (Mary Immaculate College, 2018). A greater amount of time should be devoted to PE in teacher training colleges so that teacher confidence and competence in the delivery of PE lessons can be developed. Teacher specialisation (when teachers who specialise or are very competent in one subject, such as PE, swap classes with another teacher who specialises in a different subject such as music), should also be encouraged more at a local and national level as this would potentially increase the quality of PE provision.

To ensure that children develop a high level of FMS during their primary school years, FMS levels at the end of each half year should be assessed. If trainee teachers were to undertake a module dedicated to FMS as part of their college degree and/or if a modified (i.e. more basic) version of the TGMD-2 was developed, it would be envisaged that teachers would be able to assess the FMS level of children in real time. The results of such assessments and feedback should then be passed onto parents/guardians in a similar way to the academic results (during parent-teacher meetings and through the distribution of individualised report cards). This may encourage teachers to place more of an emphasis on the quality of their teaching of FMS and PE, and encourage parents to encourage children to practice FMS and engage in PA at home. The FMS intervention conducted as part of this research (Chapter 6) found that when such an emphasis is placed on FMS, significant improvements in skill proficiency can be attained.

Teachers should also be encouraged to allow children to take short activity breaks throughout the school day. Alternatively incorporating curriculum-focused PA breaks (i.e. PA breaks with some curriculum content included) (Mahar et al., 2006) throughout the day and/or integrating PA into their academic lessons (Martin & Murtagh, 2015; Riley, Lubans, Holmes, & Morgan, 2014; Riley, Lubans, Holmes, & Morgan, 2016) could be incorporated into the school day. In this way, teachers can provide opportunities for children to engage in PA as well as enhance their learning. Studies that have investigated the effect of such activity during the school day have reported better attention (Palmer, Miller, & Robinson, 2013), better on-task behaviour (Goh et al., 2016; Mahar, 2011), enhanced enjoyment (Vazou & Smiley-Oyen, 2014), better cognitive function (Hill et al., 2010), better concentration levels (Tsai, Boonpleng, McElmurry, Park, & McCreary,

2009) and higher academic scores among children (Caterino & Polak, 1999; Gao, Hannan, Xiang, Stodden, & Valdez, 2013; Hillman & Pontifex 2009; Watson et al., 2017) in addition to positively impacting PA levels (Martin & Murtagh, 2015; Murtagh et al., 2013). It has also been found that less disciplinary intervention is required among children who engage in such activity breaks during the school day (Barry, Mosca, Dennison, Kohl, & Hill, 2003).

The digital resource developed during this research (Appendix B) which has the potential to assist in training teachers and providing parents and coaches with support on the development of FMS among children should be incorporated into teacher training courses, coaching courses and be provided to parents. Given its digital nature, the tool should be made accessible online for greater accessibility.

Given the effectiveness of this intervention, it is recommended that policy makers adapt or introduce new policies that would result in mandatory daily PA sessions. Such sessions would be FMS-based and also include activities that would facilitate children's engagement in MVPA. Health-promoting countries such as Denmark and Finland have used this strategy (adapting/introducing new school-based PA policies) in an attempt to increase PA levels and/or reduce overweight/obesity. For example, Denmark amended its Folkeskole Consolidation Act in 2014 so that primary schools are now required to deliver 45 minutes of mandatory PA every day and Grade 1 students (6-7 year olds) also receive one extra PE lesson per school week (European Commission & WHO, n.d.). In Finland, reformed national policies that require schools to provide compulsory health education and PE to children are among those believed to have contributed to the country's stabilising overweight/obesity levels (WHO, 2015). Ireland should implement policy changes at the primary school level as such changes have the potential to enhance the health of children and future generations of adolescents and adults. Furthermore, such policy changes have the potential to prevent Ireland becoming the fattest EU nation by 2030 as has been predicted (Webber et al., 2014) and also to relieve some of the substantial economic burden that comes with hypokinetic diseases such as obesity.

## 7.5 Limitations

The limitations of the current research are outlined below.

- Despite a controlled study design, it must be noted that the control and intervention schools were quite different. The intervention schools were urban single-sex schools compared to the rural mixed-sex control school. Furthermore, the intervention schools were limited in terms of facilities and policies. Each of the intervention schools had very limited yard space (approximately the size of two basketball courts for over 300 children) and a small hall to which they had access for half of the week. In one of the intervention schools, children were required to remain in their seats in their classroom for break time, were not permitted to run at break and were not allowed to use PA equipment other than skipping ropes (e.g. balls and bats) at lunch. Both intervention schools were required to wait indoors before school. In comparison, the control school were permitted to play outdoors before school and during both break and lunch time. The yard space available to the control school was vast (yard space, a synthetic grass pitch, a turf pitch). Playground markings promoted PA during break and lunch and a lunchtime football league was facilitated by the teachers among the senior classes. Children were permitted to use a range of PA equipment (e.g. nets, bats and balls) at break and lunch and a large hall (approximately three times that of the intervention) was available to the control school. Future research should acknowledge the importance of the quality and quantity of school facilities and the school ethos/culture in selecting control schools. These are important variables in the study design and may affect the results/limit the extent to which meaningful conclusions can be drawn if intervention and control schools are not matched accurately.
- The intervention was carried out among schools that were in close proximity to each other in a specific geographical location in Ireland. Further research is warranted to investigate if the findings of the current study can be extrapolated to other areas.

- Due to limited resources, the evaluation of the interventions involved only children from a limited number of class groups (with the PA intervention evaluated among senior infant and 4<sup>th</sup> classes and the FMS intervention evaluated among senior infant, 1st, 4th and 5th classes). Future research should evaluate the intervention among a sample of children from every class group (i.e. junior infants to 6<sup>th</sup> class).
- Due to the large sample size and the limited availability of Project Spraoi Research Team members and accelerometers, testing of the intervention and control groups were not conducted at the same time. For example, PA data were collected at pre-FMS intervention from the intervention groups during three different weeks (the weeks beginning 23rd September, 2nd October and 8th October) while PA data were collected from the control group during the week beginning 19th November. This meant that PA data was collected from children in the intervention and control schools in different weather conditions and across different day lengths. This difference in testing periods may have resulted in lower pre-intervention levels of PA among the control group (compared to what may have been recorded if PA data were collected at the same time period as the intervention groups) due to poor weather conditions and given that many sports clubs often cease club activities and training during the winter months. These potentially lower pre-intervention values may have subsequently resulted in a 'false' or misleading change in PA across time among the control group when calculated using post-intervention data.
- Furthermore, despite the use of objectively measured PA using tri-axial accelerometers, PA data from only a small sample of children could be included in the analysis. This was due to both limited accelerometer availability and wear time compliance. In an effort to promote wear time compliance, a parent information sheet (Appendix E.4) was distributed to children at the time of accelerometer distribution. Furthermore, an SMS message was sent to the parents/guardians each morning that the children were to wear the accelerometer. Despite instructions to wear the accelerometer during all waking hours (except during aquatic activities), anecdotal reports suggest that some children removed the accelerometers during sporting activities due to

discomfort and/or fear of breaking them (e.g. in sports such as hurling/camogie where the monitors may have been contacted by a hurl). In an effort to attain a more accurate measurement of children's PA levels, future research should consider using both accelerometers and PA diaries, or alternatively using wrist-worn accelerometers which have been found to have higher compliance when compared to hip-worn monitors (Fairclough et al., 2016).

- FMS testing was carried out with class groups of children (approximately 28-30) in a large hall at the same time. While the class group was subdivided into smaller groups (4-7 per group) and these smaller groups allocated to their own testing station, children's attention to the silent demonstration provided and their on-task behaviour may have been affected by the large amount of activity going on either in their own group while they were waiting to perform their test trials or at the other testing stations around them. FMS testing of two children at a time in the hall may assist in gaining a more accurate measure of FMS proficiency and is something future research should consider.
- FMS proficiency was measured using the TGMD-2, a tool designed and developed in the USA. The skill components required to demonstrate mastery of the skills are based largely upon the technique that can be later applied to American sports (e.g. baseball). Although the technique/components of 11 out of the 12 skills can be applied across cultures (i.e. to both Irish and American sports), correct performance of the fundamental 'baseball' strike (as outlined in the TGMD-2) differs from that of the fundamental 'hurling' strike (used in hurling and camogie which are among the most popular sports played by Irish children). The correct hand position for baseball requires that the dominant hand grips bat above the non-dominant hand. However, the opposite holds for hurling/camogie (i.e. the non-dominant hand should grip the hurl above the dominant hand). As a result, children who demonstrated a correct hurling grip in their performance of the strike were awarded a zero for the strike component that required the 'the dominant hand grips bat above the non-dominant hand'. An adapted version of the TGMD-2 may be more appropriate for use in an Irish context. Gaelic games (Gaelic football and hurling) are among most popular sports played by Irish children (and also adolescents and adults) (Fahey, Delaney and Gannon, 2005;

Sport Ireland, 2016; Woods et al., 2010). However, the TGMD-2 lacks a number of fundamental skills (e.g. the Gaelic football kick from the hand, hurling ground strike, hurling ground block) that apply to these sports due to its American origin and so a culturally relevant FMS assessment tool should be designed.

## **7.6 Conclusion**

A specialist-led PA intervention resulted in improvements in central adiposity and CRF (among 10 year olds), with no concurrent improvements in FMS or any of the other markers of health. As a result of these findings and given the positive relationship found between FMS and markers of health among children (Chapter 4) (Lubans et al., 2010; Robinson et al., 2015), a tailored motor skill intervention that aimed to improve both FMS proficiency and markers of health among children was developed and delivered. The multi-component FMS intervention resulted in significant improvements in FMS proficiency, adiposity levels and CRF (among 10 year olds) relative to the control. Given the high level of overweight/obesity and the low levels of FMS, PA and CRF among Irish children, and the positive impact that the FMS intervention had on these measures among this related cohort, policy makers should consider implementing the intervention in schools countrywide, incorporating specific FMS training into teacher training courses and altering existing primary school policies in an attempt to increase the quality and quantity of PE in schools and ultimately improve the FMS and markers of health of children.

## **7.7 Recommendations for Future Research**

A number of recommendations that future research should consider are outlined below.

- While the interventions conducted as part of this research were delivered to just two schools, the effectiveness of a step-back approach (in which Energizers would be assigned to a larger number of schools) should be investigated. The



amount of direct contact time Energizers would have with each school would be reduced (e.g. to one session per week/fortnight) but they would continue to support schools by setting up and monitoring initiatives as well as providing resources and sample lesson plans. This model, used by Project Energize in New Zealand, has been found to be both sustainable (Rush et al., 2016) and effective at improving FMS (Mitchell et al., 2013) and markers of health (Rush et al., 2012; 2014). Future research should investigate the effectiveness of a step-back approach in an Irish context.

- A nationwide evaluation of Irish pre-school children's FMS proficiency should be conducted. Recent research has highlighted the poor FMS proficiency of Irish primary school children (Bolger et al., 2017; Farmer et al., 2017) and among post-primary school children (O'Brien et al., 2016b). However, no research has been conducted among Irish pre-school children. Given that children have the potential to master FMS by the age of 6 years and that the early childhood years have been identified as a critical period for FMS development (Gallahue & Ozmun, 2006), it is essential that this development process begins during the pre-school years so that children's FMS proficiency levels are in line with the recommended levels for their age as they progress through pre-school and transition to primary school.
- Future research should investigate the relationship between FMS (actual and perceived) and organised sport. Increasing organised sport participation is a potential viable strategy to increase children's PA levels and increase the proportion of children reaching the WHO's 60 minutes of daily MVPA recommendation. Marques, Ekelund and Sardinha (2016) found that organised sports participation was positively associated with objectively measured moderate and vigorous PA levels and also with achieving the recommended daily 60 minutes MVPA among 10-18 year old Australian youth (N=973, mean age:  $14.1 \pm 2.4$  years). Furthermore, Telford, Telford, Cochrane, et al. (2016) found that Australian youths (aged 8-16 years) who participated in sport were more active, fitter and had less body fat than those who did not.

- Anecdotally, it was clear that teachers' understanding of FMS was limited and they lacked confidence in teaching them. Teachers' knowledge of FMS as well as their competence and confidence in teaching FMS should be evaluated.
- Interventions that include mandatory daily PA which focuses on FMS should be evaluated among Irish children. Kriemler et al. (2010) found that the KISS study which involved daily 45 minute PE lessons improved MVPA levels, aerobic fitness and reduced adiposity among Swiss first and fifth grade primary school children (N=502). However, there was no FMS component to the intervention. As FMS instruction can take away from other aspects of PE (e.g. fitness) (van Beurden et al., 2003), an investigation into the effect of daily PA/FMS lessons on FMS and markers of health should be conducted.
- A number of children identified that they had removed their accelerometers before they engaged in sporting activities for reasons such as discomfort and fear of breaking the monitor. Furthermore, time spent in PA while cycling and swimming cannot be measured using accelerometers and so research assessing PA levels of children should use a combination of tri-axial accelerometers and daily PA logs.
- While the current intervention was multi-component in that it consisted of school and home-based components, future interventions should place a greater emphasis on the home-based aspects and also attempt to link with the wider community. Parent information evenings, monthly PA newsletters and interactive resources such as that developed as part of this research (Appendix B) have the potential to engage parents/guardians more in their child's FMS development and encourage active lifestyles. Inviting local sports/ PA clubs into the school to participate in an FMS training workshop may encourage clubs to emphasise the importance of FMS development and provide appropriate instruction, feedback and practice during their sessions. To promote participation in organised sports, clubs should also be invited to deliver a sport-specific session to each of the class groups.
- The current research examined the relationship between childhood FMS proficiency and markers of health (also measured during childhood) among a cohort of Irish primary school children (Chapter 4). However, there is a dearth of

literature relating to the relationship between childhood FMS proficiency and markers of health in later years, particularly in an Irish context. The limited amount of existing literature that has examined childhood FMS proficiency and markers of health in subsequent years has reported positive findings. However, these investigations have been limited to the relationship between FMS and PA (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009; Lloyd et al., 2014) and FMS and CRF (Barnett, van Beurden, et al., 2008). These longitudinal studies have measured PA/ CRF either 6 (Barnett, Morgan, et al., 2008; Barnett, van Beurden et al., 2008, Barnett, van Beurden, Morgan, Brooks, Zask, et al., 2009) or 20 years (Lloyd et al., 2014) after the measurement of FMS proficiency. Future research should therefore consider assessing a wider range of markers of health (e.g. BMI, WC, BP) over a number of different time periods (e.g. after 5, 10, 15 and 20 years) to investigate the longitudinal impact of FMS development during childhood.

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