Fundamental Movement Skill Proficiency and Health among a Cohort of Irish Primary School Children

Bolger, Linda A.[1]; Bolger, Lisa E.[1]; O' Neill, Cian[1]; Coughlan, Edward[1]; Lacey, Seán[1]; O'Brien, Wesley[2] and Burns, Con[1]

[1]Cork Institute of Technology, Cork, Ireland;
[2]University College Cork, Cork, Ireland;

Email Addresses:
Bolger, Linda A.[1]; linda.bolger@mycit.ie
Bolger, Lisa E.[1]; lisa.bolger@mycit.ie
O' Neill, Cian[1]; cian.oneill@cit.ie
Coughlan, Edward[1]; edward.coughlan@cit.ie
Lacey, Seán[3]; sean.lacey@cit.ie
O'Brien, Wesley[2]; wesley.obrien@ucc.ie
Burns, Con[1]; con.burns@cit.ie

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Abstract

Purpose: This study aimed to investigate the relationship between fundamental movement skills (FMS) and markers of health among a cohort of Irish primary school children. Methods: Participants (N=296, mean age: 7.99±2.02 years) were senior infant (n=149, mean age: 6.02±0.39 years) and 4th class (n=147, mean age: 9.97±0.40 years) students from 3 primary schools in Cork, Ireland. FMS proficiency (TGMD-2) and markers of health (BMI percentile, waist circumference percentile, blood pressure percentiles, resting heart rate, cardiorespiratory fitness, objectively measured physical activity; PA) measurements were recorded. Correlation and hierarchical stepwise multiple linear regression analyses were conducted to investigate the relationship between FMS and markers of health. Results: A small**,** positive relationship was found between FMS (Gross Motor Quotient; GMQ) and cardiorespiratory fitness with small negative correlations between GMQ and 550 m time SDS among 6 year olds ($r(129)=-.286$, $p<0.05$) and 10 year olds ($r(132)=-.340$, $p<0.05$). A moderate, positive correlation was found between GMQ and light PA ($r(71)=.400$, $p<0.05$). Small positive correlations were revealed between GMQ and moderate PA ($r(71)=.259$, $p<0.05$)**,** and GMQ and total PA ($r(71)=.355$, $p<0.05$). After adjusting for age, sex, the interaction effect of age and sex, and school attended, FMS explained 15.9% and 24.8% of the variance in 550 m time SDS among 6 and 10 year olds, respectively, and 6% and 6.5% of the variance in light PA and moderate PA, respectively. After adjusting for age and sex, FMS explained 11.6% of the variance in total PA. Conclusion: A wide range of FMS is important for children's cardiorespiratory fitness and PA.

Keywords: cardiovascular fitness, elementary school, gross motor skills, physical activity

Fundamental movement skills (FMS) are basic movement patterns that facilitate participation in sport and physical activity (PA; Gallahue & Ozmun, 2006). They can be categorized into three subgroups; locomotor (LOCO), object-control (OC), and stability skills (Lubans et al., 2010). FMS proficiency is positively associated with many physiological, psychological and behavioral benefits (Lubans et al., 2010) including fitness (Burns et al., 2017) and PA levels (Logan et al., 2015). Burns et al. (2017) reported a negative, albeit very small, relationship between LOCO skill proficiency and metabolic syndrome score among children, emphasizing that further benefits such as a reduced risk of cardio metabolic disease may also be associated with FMS proficiency. Although a positive association between FMS proficiency and physiological markers of health such as cardiorespiratory fitness (CRF; Barnett et al., 2008; Marshall & Bouffard, 1997; Okely, Booth, & Patterson, 2001), PA (Capio et al., 2014; Cohen et al., 2014), and weight status (Lubans et al., 2010; Slotte et al., 2015) have been reported, further validation is sparse. Furthermore, few researchers have examined the relationship between FMS and other markers of health such as resting heart rate (RHR), blood pressure (BP), and PA levels of different intensities e.g., light PA (LPA), moderate PA (MPA), vigorous PA (VPA), and moderate-to-vigorous PA (MVPA).

In a review article, Lubans et al. (2010) reported a positive relationship between FMS competency and health. However, only three out of the 21 studies that were included were 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, and used a process-oriented FMS assessment tool (Marshall & Bouffard, 1997). In addition to this review, Haga (2009) found that children with low motor competence recorded lower CRF scores than children with high motor competence, which provides further evidence to suggest that motor competence is associated with more favorable CRF. It should be noted however that the sample size in the study was limited

(N=18). Burns et al. (2017) also found a positive relationship (albeit small) between FMS and CRF among children from low-income elementary schools.

In a review article, Logan et al. (2015) reported a small to moderate positive relationship between FMS and PA among 6-12 year olds. 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 were carried out among 6-12 year olds. Studies that have investigated the relationship between FMS and objectively-measured PA have produced mixed findings (Barnett et al., 2015; Cohen et al., 2014). Among children from low-income communities, it was found that no correlation existed between LOCO skill proficiency and daily MVPA (Cohen et al., 2014). However, OC competency was positively related to daily MVPA (Cohen et al., 2014). This correlation was small in size. Similar mixed conclusions were reported by Capio et al. (2014), who found that FMS proficiency was moderately related to PA during weekend days but not weekdays, among a sample of Filipino children. 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, LOCO standard score and GMQ were negatively associated with the percent of time spent in MVPA, with moderate correlations reported. Furthermore, Barnett et al. (2015) found that OC proficiency was not associated with MVPA among a sample of 4-8 year old children.

Many researchers have investigated the relationship between FMS and weight status among youth (Lubans et al., 2010; O'Brien et al., 2016; Slotte et al., 2015; Spessato et al., 2013). Slotte et al. (2015) reported that there was a small to moderate negative relationship between FMS and adiposity (BMI, waist circumference, body fat percentage and abdominal fat percentage) among children (albeit, only 5 of the 12 FMS from the Test of Gross Motor Development-2 were measured in the study.) Spessato 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 waist circumference-to-height ratio (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 among Irish children (O'Brien et al., 2016). 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 weight status (Cliff et al., 2009; Lubans et al., 2010; Siahkouhian et al., 2011; Slotte et al., 2015) has been examined. 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, RHR, 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.

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 and improve the nutritional habits 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 who were postgraduate researchers with undergraduate degrees in the area of sport and exercise. 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. Children (N=296, mean age: 7.99±2.02 years) from the senior infant (n=149, mean age: 6.02±0.39 years) and 4th class (n=147, mean age: 9.97±0.40 years) cohorts provided written assent and written parental consent (70%) for their involvement in the study. As testing was carried out across a number of days (FMS, CRF and physical measurements were measured on different days due to time constraints), not all children completed all measurements as some were absent from school on some of the testing days. Ethical approval was obtained from Cork Institute of Technology Research Ethics Review Board.

Fundamental Movement Skills

FMS proficiency was measured using the Test of Gross Motor Development-2 (TGMD-2), which is valid and reliable for 3-10 year olds (Ulrich, 2000). The TGMD-2 consists of 12 skills; 6 LOCO (run, leap, hop, gallop, slide and horizontal jump) and 6 OC (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. (2016). Children were provided with a silent demonstration of the skill to be tested, by a trained test administrator. Test administrators had previously received training during a 3 hour practical workshop with a researcher with over 6 year experience administering and scoring the TGMD-2. Children subsequently performed one familiarization and two test trials, with both test trials recorded. This was repeated for the 12 skills.

The recordings of the test trials were uploaded to a laptop and analyzed 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 LOCO skills were summed to give a LOCO subset score (range 0-48) and the raw skill scores of the OC skills were summed to give an OC subset score (range 0-48). LOCO and OC subset scores were subsequently converted to LOCO standard score (LOCO SS) and OC standard score (OC SS) respectively, using age- and sex-specific conversion tables in the TGMD-2 manual. 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).

Intra and inter-rater reliability were established using (a randomly selected) 10% of the collected sample before the FMS were scored by the two principal investigators. Intra- and inter-reliability scores across the 12 FMS ranged from 89-99% agreement (mean: 93.41%).

Physical Measurements

Physical measurements taken were height, mass, waist circumference (WC), RHR and BP. These measurements were collected in a small, specially designated testing room in each school. Children arrived to the testing room in groups of approximately 5-8 children. Prior to measurements, children removed their shoes and heavy clothing (e.g., school jumper). Children moved from one measurement station to the next and were instructed to sit quietly while waiting to be tested for the next measure if they had finished before the next station was free. Height was measured to the nearest 0.1cm using a Leicester portable height scales. Mass was measured to the nearest 0.1kg using a Tanita WB100MZ portable electronic scale. WC was measured to the nearest 0.1cm using a non-stretch Seca 200 measuring tape. Measurements were taken from the right side of the child, who stood with hands by the side, two feet together. A child's WC was measured as the circumference of the narrowest point of the abdomen between the lower costal border and the top of the iliac crest, perpendicular to the long axis of the trunk. RHR (to the nearest beat per minute) and BP (to the nearest mmHg) were measured using an Omron M2 Basic Auto Blood Pressure Monitor. Children sat quietly for approximately 5 minutes (the duration of time it took for child before them to be tested) before having their RHR and BP tested. RHR and BP were measured with the cuff positioned on the upper left arm of the child who was seated and the left arm relaxed and raised on a pillow. BP was measured to ±5.0 U and ±10 mmHg.

Each measurement was taken twice, with a third necessary if the first two differed by a specified value (>0.1cm for height, >0.1kg for mass, >0.1cm for WC, >10 bpm for RHR and >10 mmHg for BP). For each measured variable, the mean of the closest two measurements was calculated for each child. This value was used in the analyses. The Excel add-in LMS-growth programme (version 2.77) was used to calculate percentile scores from the British 1990 child growth reference data for age- and sex-specific percentiles of BMI (Cole, Freeman and Preece, 1995), WC (McCarthy et al., 2001) and systolic and diastolic BP (Jackson, Thalange and Cole, 2007).

Cardiorespiratory Fitness (CRF)

CRF was measured in groups of 12-15 using a 550 meter walk/run test (Albon, Hamlin & Ross, 2010). A 110-meter rope was laid in an oval shape on a flat grass area. Following a warm up lap of the oval shape (which consisted of jogging, high knees, heel flicks, skipping and sprinting), children were divided into groups of 3-4, and each group was assigned to an evaluator. Children were instructed to complete five laps of the oval shape as fast as they could. Run/walk times were recorded to the nearest second using a stopwatch. Time taken to complete the 550 m was converted from minutes and seconds, into total seconds. Age- and sex-specific

550 m run time standard deviation scores (SDS) were calculated using the run centile curves developed by 'Project Energize' evaluation data (Rush & Obolonkin, 2014).

Physical Activity (PA)

PA was measured using tri-axial ActiGraph GT3X accelerometers (Fort Walton Beach, FL, USA). A random sample of the children received accelerometers (n=121), due to limited accelerometer availability. Children 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 analyze the data. Data were collected and stored in 5-second epochs. Of the 121 children who received accelerometers, 76 (63%) met the required wear time of at least three weekdays and one weekend day, with a minimum of 10 hours recorded wear time per day (Riddoch *et al.*, 2004). Non-wear times were identified as 20 minutes of consecutive zeros. The first day of accelerometer wear time was removed from the dataset to allow for subject reactivity (Esliger *et al.*, 2005). Cut-points developed by Evenson et al. (2008) were used to calculate average daily LPA, MPA, VPA and MVPA. Average daily total PA (TOTAL PA) was calculated as the sum of LPA and MVPA).

Statistical Analysis

To identify if the nature and strength of these relationships differ across childhood, correlations between FMS variables and 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=76), 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. Correlations were classified using the absolute criterion; non-existent (r=0-0.19), low (r=0.20-0.39), moderate (r=0.40-0.59), moderately high (r=0.60-0.79) and high (≥0.80; Zhu, 2012). If correlation analysis revealed a relationship between FMS (GMQ score) and a marker of health, hierarchical forward entry 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 (having adjusting for age, sex, the interaction effect of age and sex; age*sex, and school attended). The regression analysis was carried out as follows: The dependent variable (e.g., 550 m time SDS) was entered as the dependent variable in the linear regression dialog box. Age and sex were entered in the first step (Block 1), and 'stepwise' was selected from the 'method' dropdown menu. The 12 individual skills (raw scores) were entered in the second step (Block 2) and again, 'stepwise' was selected from the 'method' dropdown menu. The regression model was run a second time, this time with age, sex and age*sex entered in the first step. The regression model was run a third time with age, sex, age*sex and school (entered as three dummy variables; school 1, school 2 and school 3) in block 1. The results of the final regression model are reported as well as the model that explained the largest amount of variance in each of the selected variables.

Results

Participants (N=296, mean age: 7.99±2.02 years) were primary school children from senior infants (n=149, mean age: 6.02±0.39 years) and 4th class (n=147, mean age: 9.97±0.40 years). Children in senior infants and 4th class are subsequently referred to as '6 year olds' and '10 year olds', respectively. Table 1 presents descriptive data of the children who participated in the study while Table 2 presents the PA results obtained from the subsample from whom PA was measured (n=76, 46% 6 year olds).

Table 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)	149	6.02 ± 0.39	147	9.97 ± 0.40
Height (cm)	145	115.82 ± 5.35	146	140.67 ± 5.68
Weight (kg)	145	21.57 ± 3.00	146	35.39 ± 6.25
FMS				
Locomotor standard score	144	11.05 ± 2.08	144	8.64 ± 1.97
Object-control standard score	138	8.88 ± 1.80	144	7.35 ± 1.97
Gross motor quotient	138	99.98 ± 8.54	144	87.96 ± 8.88
Markers of health				
550m time standard deviation score	141	0.72 ± 0.72	136	0.41 ± 0.94
Resting heart rate (bpm)	144	87.86 ± 11.71	145	79.67 ± 11.86
BMI percentile	145	57.48 ± 25.74	146	61.45 ± 26.52
Waist circumference percentile	144	48.66 ± 28.90	146	56.32 ± 28.29
Systolic blood pressure percentile	144	39.90 ± 29.83	145	34.70 ± 32.26
Diastolic blood pressure percentile	144	59.56 ± 29.83	145	62.63 ± 26.81

Table 2: Physical activity data

	Mean ± SD
Light physical activity (minutes/day)	191.68 ± 31.86
Moderate physical activity (minutes/day)	33.48 ± 7.87
Vigorous physical activity (minutes/day)	26.43 ± 12.46
Moderate-to-vigorous physical activity (minutes/day)	59.91 ± 18.47
Total physical activity (minutes/day)	251.59 ± 43.03

The relationships between the FMS variables and the collected physical measurements are presented in Table 3 (6 year olds) and Table 4 (10 year olds), respectively.

There were small, negative correlations found among the 6 year old cohort between GMQ and 550 m time SDS ($r(129)=-.286$, $p<0.05$, small effect size), and OC SS and 550 m time SDS ($r(129)=-.324$, $p<0.05$, small effect size). No correlation was observed between LOCO SS and 550 m time SDS among the 6 year old group. Among the 10 year old cohort, there was also a small, negative correlation between GMQ and 550 m time SDS ($r(132)=-.340$, $p<0.05$, small effect size). However, in contrast to the 6 year old group, there was a small, negative correlation between LOCO SS and 550 m time SDS ($rs(132)=-.362$, $p<0.05$, small effect size), with no correlation between OC SS and 550 m time SDS among the 10 year olds. There was also a small, negative correlation found between LOCO SS and RHR ($sr(140)=-.204$, $p<0.05$, small effect size) among the 10 year old cohort.

Table 3: Correlations between FMS variables (locomotor standard score, object-control standard score and gross motor quotient scores) and physical measurements for 6 year olds

	Locomotor Standard Score (n=136-141)	**Object-control Standard Score (n=131-136)**	**Gross Motor Quotient (n=131-136)**
550m time standard deviation score	-.098	-.324**	-.286**
Resting heart rate	-.092	-.063	-.114
BMI percentile	-.082	-.133	.132
Waist circumference percentile	.144	-.012	.109
Systolic blood pressure percentile	.107	.017	.116
Diastolic blood pressure percentile	.086	.021	.101

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

Table 4: Correlations between FMS variables (locomotor standard score, object-control standard score and gross motor quotient scores) and physical measurements for 10 year olds

	Locomotor Standard Score (n=134-143)	**Object-control Standard Score (n=134-143)**	**Gross Motor Quotient (n=134-143)**
550m time standard deviation score	-.362**	-.113	-.340**
Resting heart rate	-.204*	.029	-.101
BMI percentile	-.165*	-.097	-.166*
Waist circumference percentile	-.168*	.025	-.096
Systolic blood pressure percentile	.019	.005	-.016
Diastolic blood pressure percentile	.035	.100	.058

*p<0.05, **p<0.01

The relationships between the FMS variables and PA are presented in Table 5. Small, positive correlations were found between LOCO SS and LPA ($r(74)=.239$, $p<0.05$), and OC SS and LPA ($r(71)=.335$, $p<0.05$). A moderate, positive correlation was found between GMQ and LPA ($r(71)=.400$, $p<0.05$). Small, positive correlations were found between LOCO SS and MPA ($r(74)=.230$, $p<0.05$), OC SS and MPA ($r(71)=.202$, $p>0.05$) and GMQ and MPA ($r(71)=.259$, $p<0.05$). Small, positive correlations were also revealed between all three FMS variables and total PA (r range: .252 to .355, $p<0.05$).

Table 5: Correlations between FMS variables (locomotor standard score, object-control standard score and gross motor quotient scores) and physical activity

	Locomotor Standard Score (n=76)	**Object-control Standard Score (n=73)**	**Gross Motor Quotient (n=73)**
Light physical activity	.239*	.335*	.400**
Moderate physical activity	.230*	.202	.259*
Vigorous physical activity	.115	-.003	.053
Moderate-to-vigorous physical activity	.175	.084	.146
Total physical activity	.252*	.281*	.355*

*p<0.05, **p<0.01, *total physical activity= light physical activity + moderate-to-vigorous physical activity*

As correlations were identified between (i) GMQ and 550 m time SDS among 6-and 10 year olds), (ii) GMQ and LPA, (iii) GMQ and MPA and (iv) GMQ and total PA, stepwise multiple linear regression analysis was used to further investigate these relationships. Regression analysis revealed that after adjusting for age, sex, age*sex and school, FMS skill scores explained 15.9% and 24.8% of the variance in 550 m time SDS among 6 and 10 year olds, respectively (Table 6). The full model (including the variables that were adjusted for) for 6 year olds explained 20.2% of the variance in 550 m time SDS (Adjusted R^2=0.202, F(4, 125)=9.140, p<0.05), with the statistically significant predictors being the kick (β=-.080, p<0.05, 95% CI [-0.140, -0.019]), dribble (β=-0.081, p<0.05, 95% CI [-0.137, -0.025]) and hop (β=-.097, p<0.05, 95% CI [-0.156, -.0.038]). The model predicts that for each unit increase in kick score, 550 m time SDS would decrease by 0.080 units, each unit increase in dribble score would result in a 0.081 unit decrease in 550 m time SDS and each unit increase in hop score would result in a decrease of 0.097 units in 550 m time SDS. Having adjusted for age, sex, age*sex and school attended, the model for 10 year olds explained 24.8% of the variance in 550 m time SDS. The full model (including age, sex, age*sex and school) for 10 year olds explained 27.2% of the variance in 550 m time SDS (Adjusted R^2=0.272, F(6, 127)=9.290, p<0.05). Statistically significant predictors in the model were school 1 (β=--.537, p<0.05, 95% CI [-0.929, -0.145]), hop (β=-0.108, p<0.05, 95% CI [-0.207, -0.008]), jump (β=-0.217, p<0.05, 95% CI [-0.307, -0.127]), roll (β=-0.111, p<0.05, 95% CI [-0.190, -0.032]), gallop (β=-0.156, p<0.05, 95% CI [-0.275, -0.038]) and catch (β=-0.142, p<0.05, 95% CI [-0.282, -0.003]). This model predicts that children who attended school 1 had a 550 m time SDS score that was 0.537 units lower than those from the other two schools, and for each unit increase in hop, jump, roll, gallop and catch scores, there would be 0.108, 0.217, 0.111, 0.156 and 0.142 unit decrease in 550 m time SDS, respectively.

Regression analysis conducted with LPA and MPA, respectively as the outcome variables, revealed that after adjusting for age, sex, age*sex and school attended, FMS skills explained 6.0% and 6.5% of the variance in LPA and MPA respectively (Table 7). The full model for LPA explained 27.9% of the variance (Adjusted R^2=0.279, F(3, 69)=10.291, p<0.05). Age (β=-7.281 p<0.05, 95% CI [-10.517, -4.045]) and the roll (β=5.036, p<0.05, 95% CI [1.180, 8.891]) were identified as statistically significant predictors in the model. The model predicts that for each yearly increase in age, LPA would decrease by 7.28 minutes and for each unit increase in roll score, LPA would increase by 5.04 minutes. A total of 28.9% of the variance in MPA was explained by the regression model presented in Table 7 (Adjusted R^2=0.289, F(2, 70)=15.658, p<0.05). Age*sex (β=-0.962, p<0.05, 95% CI [-1.335, -0.590]) and the jump (β=1.207, p<0.05, 95% CI [0.328, 2.087]) were statistically significant predictors in the model. This model predicts that the MPA level of a girl is lower than that of a boy by 0.962 times her age. It also predicts that for each increased unit in jump score, MPA would increase by 1.21 minutes.

The regression analysis for total PA returned a model in which there were no FMS included. The model in which age*sex (β=-14.078, p<0.05, 95% CI [-20.511, -7.645]) and sex (β=92.951, $p<0.05$, 95% CI [37.978, -3.875]) were the statistically significant predictors, explained 23.7% of the variance in total PA (Adjusted $R^2=0.237$, $F(2, 70)=12.209$, $p<0.05$)(Table 8(a)). After adjusting for age and sex only, the analysis revealed a model that explained 11.6% of the variance in total PA (Table 8(b)). The full model (i.e., including age and sex) explained 28.5% of the variance in 550 m SDS (Adjusted $R^2=0.285$, $F(4, 68)= 8.183$, $p<0.05$), with the statistically significant predictors being age (β=-10.724, $p<0.05$, 95% CI [-15.239, -6.209]), sex (β=-21.735, $p<0.05$, 95% CI [-39.595, -3.875]), the roll (β=7.285, $p<0.05$, 95% CI [2.056, 12.515]) and the jump (β=6.797, $p<0.05$, 95% CI [7.787, 11.807]). This model predicts that for each yearly increase in age, total PA would decrease by 10.72 minutes. It predicts that a girl would accumulate 21.74 minutes less total PA than a boy. The model also predicts that for each unit increase in roll and jump score, total PA would increase by 7.29 and 6.80 minutes, respectively.

Table 6: Hierarchical stepwise multiple linear regression analysis explaining variance in 550m time SDS for 6 and 10 year olds

	Unstandardized Beta	**Standardized Beta**	**95% Confidence Interval**		**Adjusted R^2**
			Lower Bound	**Upper Bound**	
6 year olds					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	
10 year olds					0.272**
Constant	5.056**		3.607	6.504	
School 1	.-.537*	-.216	-.929	-.145	
Hop	-.108*	-.167	-.207	-.008	
Jump	-.217**	-.362	-.307	-.127	
Roll	-.111**	-.210	-.190	-.032	
Gallop	-.156*	-.195	-.275	-.038	
Catch	-.142*	-.156	-.282	-.003	

*p<0.05, **p<0.01

Table 7: Hierarchical stepwise multiple linear regression analysis explaining variance in light and moderate physical activity

	Unstandardized Beta	**Standardized Beta**	**95% Confidence Interval**		**Adjusted R^2**
			Lower Bound	**Upper Bound**	
Outcome: Light physical activity					0.279**
Constant	233.677**		204.677	262.677	
Age	-7.281**	-.471	-10.517	-4.045	
Age*Sex (0=boys)	-1.350	-.181	-2.901	.200	
Roll	5.036	.278	1.180	8.891	
Outcome: Moderate physical activity					0.289**
Constant	31.175**		26.592	35.758	
Age*Sex (0=boys)	-.962**	-.516	-1.335	-.590	
Jump	1.207**	.274	.328	2.087	

*p<0.05, **p<0.01

Table 8: Hierarchical stepwise multiple linear regression models explaining variance in total physical activity

	Unstandardized Beta	Standardized Beta	95% Confidence Interval		Adjusted R^2
			Lower Bound	Upper Bound	
(a) Outcome: Total physical activity					0.239**
Constant	260.637**				
Age*sex (0=boys)	-14.049**	-1.387	-20.297	-7.801	
Sex	92.525**	1.076	39.495	145.555	
(b) Outcome: Total physical activity					0.285**
Constant	284.076**		239.458	328.694	
Age	-10.724**	-.507	-15.239	-6.209	
Sex (0=boys)	-21.735*	-.249	-39.595	-3.875	
Roll	7.285**	.294	2.056	12.515	
Jump	6.797**	.282	7.787	11.807	

*p<0.05, **p<0.01

Discussion

A small, negative relationship was found between GMQ and 550 m time SDS among both 6 and 10 year old groups, suggesting that those with higher FMS proficiency 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 small correlation (*r*=.28) 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±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±0.40 years). Results of the current study, similar to Burns et al. (2017), found a small, positive correlation between LOCO skills and CRF (*r*=.34) and no correlation between OC skills and CRF (r=-.113). Marshall and Bouffard (1997) also reported similar findings with a small, positive correlation reported between LOCO and CRF (*r*=.32), and no correlation between OC and CRF (*r*=.18) 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), and total FMS score and CRF (*r*=.35), with small, positive correlations found. However, in contrast to the current study, Marshall and Bouffard (1997) also reported a small, positive correlation (*r*=.31) between LOCO and CRF among 5-6 year old children.

The relationship, albeit small between FMS and 550 m time SDS is very encouraging given that CRF is a very important marker of health. 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 correlation between GMQ and CRF is due to a greater engagement in PA (possibly organized 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 correlation between OC SS 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 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 correlation between OC SS 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 relationship between LOCO SS and CRF (and RHR) 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 LOCO skills) participate in greater amounts of organized sport than their less efficient counterparts.

Furthermore, within sporting settings, children who have greater LOCO skills often play in central positions on sporting teams and so those with higher LOCO have the opportunity to enhance their CRF (and reduce their RHR). A possible explanation for the lack of correlation between LOCO SS and CRF (and between LOCO SS and RHR) among 6 year olds may be that the difference in children's movement capabilities may not be 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 24.8% of the variance in 550 m time SDS among 6 and 10 year olds, respectively (after adjusting for age, sex, the interaction of age and sex, and school attended). A larger amount of the variance in 550 m time SDS was explained among the 10 year old group (compared to the younger group), 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 (this study) and adolescents (Okely et al., 2001), Barnett 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 hop was identified as a predictor of 550 m SDS for both the 6 and 10 year old cohorts suggesting that the development of this skill in particular is important for children's CRF. However, this was the only skill that featured in both the 6 and 10 year olds' models, indicating that a range of skills is important for children's CRF.

The negative relationship between FMS and 550 m 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 provide support for this explanation. Given that regression analysis revealed that FMS explained 6% and 6.5% of the variance in LPA and MPA, respectively (after adjusting for age, sex, age*sex and school attended), and 11.6% of the variance in total PA (after adjusting for age and sex), the development of FMS may has the potential to enhance PA levels among children. Although there was no correlation between FMS and MVPA, correlations between LPA, MPA 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, video games etc.) any increase in PA may bring about health benefits (even though it may not be MVPA. Further to this, children with greater FMS proficiency may be able to take part in PA at higher intensities than those less skilled (Fairclough & Stratton, 2006). Research shows that the greater the exercise intensity, the greater the improvements in CRF (Swain & Franklin, 2002).

Correlation analysis revealed that there was no relationship between either FMS and WC percentile or FMS and BMI percentile. To date, mixed findings for the relationship between FMS and BMI have been reported (Siahkouhian et al., 2011; Spessato et al., 2013; Slotte et al., 2015). When a negative correlation between FMS and BMI is found, it appears to be largely due to the negative relationship between LOCO skills and BMI, rather than the relationship between OC skills and BMI. For instance, Siakhouhian et al. (2011) found **a** negative relationship between BMI and three out of four LOCO skills tested (*r* range: .24 to .46) but with none of the four OC skills tested. Among an Irish cohort, albeit adolescents, O'Brien et al. (2016) found negative correlations between LOCO and BMI among girls (*r*=-.341) and boys (r=-.367) but no relationship between OC and BMI among either girls or boys. 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., 2016). 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 are likely due to other factors such as the quality and amount of instruction, feedback and practice experience.

Based on the TGMD-2's GMQ classification (<70=very poor, 0-79=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. 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. To increase the provision of PE for primary school children, mandatory PE time (of longer duration than the currently recommended one hour) should be introduced. With low FMS proficiency reported among Irish primary school children (Bolger et al., 2017), the quantity and quality of PE delivered to Irish primary school children warrants attention. The Irish primary school PE curriculum which is delivered to children by the classroom teacher, is designed to target 6 strands of activities (games, athletics, outdoor adventure, dance, aquatics and gymnastics). Despite 6 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 5 strands during PE during their previous year in school. The delivery of lessons in a narrow range of activities may be due to a lack of competence among classroom teachers in teaching PE, an issue that has been previously highlighted among Australian primary school teachers (Morgan & Hansen, 2008). The low FMS proficiency levels that have been reported among Irish primary school children (Bolger et al 2017) also suggest this and highlight the need for intervention among primary schools. 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 (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 give appropriate instruction and feedback to their students) as well as a greater provision of time for PE in the curriculum (to allow for practice and opportunities to receive appropriate feedback). PE which is currently 'recommended' (to be carried out for a minimum of 60 minutes per week), should also 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 standardized test scores in subjects such as English and maths.

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 6th class (4-12 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.

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 should consider the use of wrist-worn accelerometers to collect PA data 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. Some children reported removing their accelerometers before playing sport, which may have also led to an underestimation of PA. To obtain a more accurate measurement of PA levels, PA diaries in conjunction with accelerometers should be considered. capture physical activities undertaken during 'non-wear' times.

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 OC proficiency and MVPA, and a one-way relationship from MVPA to LOCO 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, future researchers should consider investigating the relationships between FMS and markers of health with children stratified by both of these variables as had been carried out by Okely et al. (2001) among an adolescent cohort.

Conclusion

FMS proficiency was negatively related to 550 m time SDS and 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 relationship between FMS and the other markers of health (RHR, WC percentile, BMI percentile and BP percentiles) among 6 or 10 year old 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 variety of physical activities and sport, and thus healthy, active lifestyles.

What does this paper add?

Given predictions that Ireland is on track to become the fattest of 53 nations by 2030 (Webber et al., 2014) and concurrent low fitness levels (Woods et al., 2010), avenues that have the potential to kerb such adverse trends (one of these being FMS; Stodden et al., 2008) warrant further investigation. Many researchers have examined the relationship between children's FMS proficiency and markers of health (Lubans et al., 2010). However, 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 and (ii) relationship between FMS and markers of health, among Irish children. Furthermore, researchers who have investigated the relationship between FMS and markers of health have often done so using a single marker of health (e.g.**,** habitual PA, weight status) (Cohen et al., 2014; Siahkouhian et al., 2011). This paper not only provides data relating to Irish primary school children's FMS proficiency but also examines the relationship between FMS and a comprehensive battery of markers of health (CRF, PA of different intensities, BMI, WHtR and BP) among children.

Conflict of Interest

The authors declare no conflict of interest.

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