Journal of Motor Learning and Development, 2018, 6, 81–100
https://doi.org/10.1123/jmld.2017-0003

Human Kinetics
ORIGINAL RESEARCH

Age and Sex Differences in Fundamental Movement Skills Among a Cohort of Irish School Children

Lisa E. Bolger, Linda A. Bolger, Cian O' Neill, and Edward Coughlan
Cork Institute of Technology

Wesley O'Brien
University College Cork

Seán Lacey and Con Burns
Cork Institute of Technology

The purpose of this study was to assess the fundamental movement skill (FMS) proficiency of Irish primary school children relative to age and sex. Data collected were baseline measures for *Project Spraoi*, a physical activity (PA) and nutrition-based intervention. Participants ($N = 203$) were senior infant ($n = 102$, M age: 6.0 ± 0.4 years) and fourth class ($n = 101$, M age: 9.9 ± 0.4 years) children from three primary schools in the south of Ireland. FMS testing was conducted using the Test of Gross Motor Development-2 (TGMD-2), assessing six locomotor and six object-control skills. Analysis of variance (ANOVA) was used to assess age and sex related differences in FMS proficiency. Older children scored significantly higher than younger children in both locomotor ($p < .05$) and object-control score ($p < .05$). Boys scored significantly higher than girls in object-control score ($p < .05$), while girls scored significantly higher in locomotor score ($p < .05$). FMS levels among Irish primary school children are similar to children worldwide, with age and sex differences evident. Early interventions, aimed at improving FMS, are warranted among Irish primary school aged children as greater proficiency is related to greater PA participation and numerous health benefits.

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

L.E. Bolger, L.A. Bolger, O' Neill, Coughlan, and Burns are with the Dept. of Sport, Leisure and Childhood Studies, Cork Institute of Technology, Cork, Ireland. O'Brien is with the School of Education, University College Cork, Cork, Ireland. Lacey is with the Dept. of Mathematics, Cork Institute of Technology, Cork, Ireland. Address author correspondence to Lisa E. Bolger at lisa.bolger@mycit.ie.

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

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

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

Both age and sex have been found to influence FMS proficiency among children (Bardid et al., 2016; Bryant, Duncan, & Birch, 2014; Freitas et al., 2015; Spessato, Gabbard, Valentini, & Rudisill, 2013). Older children typically exhibit superior FMS proficiency than their younger counterparts (Bardid et al., 2016; Freitas et al., 2015; Mitchell et al., 2013; Spessato et al., 2013) as a result of natural maturation and additional instruction, practice and feedback (Charlesworth, 2016).

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

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

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

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

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

To date, no published research exists that has examined FMS levels among Irish primary school children. While a study including the assessment of FMS in Northern Ireland was conducted by Breslin, Murphy, McKee, Delaney, and Dempster (2012), the scoring protocol of the adapted tool developed was not described nor were the current levels among the cohort reported. International comparisons reveal that Irish children have low PA levels as well as high levels of sedentary behavior (Tremblay, 2014). Furthermore, according to a World Health Organization study involving 53 European countries, Ireland has been predicted to be the fattest of these nations by 2030 (Webber et al., 2014) and, thus,

an investigation into the FMS levels of Irish children may highlight FMS as an area with the potential for improvement. Based on the associations between FMS and numerous benefits, improving FMS may be one such mechanism to help promote health and wellbeing and combat the rise in obesity that has been predicted in our country (Webber et al., 2014). Therefore, the aim of this research was to examine the current FMS proficiency levels among Irish primary school children, as well as to investigate any age- and sex-related differences that may exist among this cohort. Based on the declining trend that is apparent in FMS proficiency, it is hypothesized that Irish primary school children will demonstrate similarly low levels to those reported among children worldwide in recent literature, irrespective of cultural and sporting habits.

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

Methods

Participants

Data collection was conducted as part of baseline measurements for Project Spraoi, a primary school-based physical activity and nutrition intervention project (Coppinger, Lacey, O'Neill, & Burns, 2016). Three primary schools (1 rural mixed and 2 urban single sex: 1 boys and 1 girls) from a region in southern Ireland were invited to partake in the project.

Ethical approval was obtained from Cork Institute of Technology Research Ethics Review Board. From a total of 301 eligible children from senior infants and fourth class, written informed parental consent for involvement in the study was provided and returned for 203 children (110 boys, 54.2% and 93 girls, 45.8%; 67% consent rate). Of the 203 participating children, 102 were from senior infants ($M = 6.0 \pm 0.4$ years) and 101 from fourth class ($M = 9.9 \pm 0.4$ years).

Anthropometric Measurements

Anthropometric data were collected prior to FMS assessment. Height was measured to an accuracy of 0.1 cm using a Leicester portable height scales. Body mass was measured to an accuracy of 0.1 kg, using a Tanita WB100MZ portable electronic scale. Shoes were removed for both measures. BMI was calculated as weight (kg) divided by height (m^2). Children were classified into BMI categories (i.e., normal, overweight/obese) using age and sex-specific cut-off points developed by Cole, Bellizzi, Flegal, and Dietz (2000).

FMS Assessment

FMS proficiency was measured using the Test of Gross Motor Development-2 (Ulrich, 2000). This FMS assessment instrument, which has been used worldwide to assess FMS proficiency among children (Bakhtiar, 2014; Burrows et al., 2014; Cliff et al., 2009; Hardy et al., 2010; Spessato et al., 2013), is a criterion and norm-referenced, process-oriented tool that has been found to be both valid and reliable

for use among children aged three to 10 years (Ulrich, 2000). The TGMD-2 consists of two subsets of skills: locomotor and object-control. The six locomotor skills assessed are the run, gallop, slide, leap, hop, and horizontal jump. The six object-control skills assessed are the kick, catch, overhand throw, strike, underhand roll, and dribble.

Data Collection

Data were collected over four days in October 2014, by a cohort of nine trained evaluators from the Project Spraoi Research Team (postgraduate researchers and staff of Cork Institute of Technology and University College Cork). Prior to testing, evaluators completed an FMS-testing training workshop which was delivered by a research practitioner with extensive experience of using the TGMD-2 (O'Brien, Belton, & Issartel, 2016). Testing of each class group (22–30 children) took approximately one hour and was carried out in a large, indoor sports hall. The testing procedure replicated the protocol used by previous researchers in an Irish school-context (O'Brien et al., 2016). The hall was divided into four stations with the following skills tested at each station: (1) run, leap, hop, gallop, slide; (2) catch, throw, roll; (3) kick, strike; and (4) dribble and jump. Groups of five to eight children were allocated to each station. When skills were completed at a station, the groups simultaneously rotated clockwise until all 12 skills had been evaluated. A demonstration of each skill was provided by an evaluator assigned to each station. Each child performed the skill three times, consisting of one familiarization trial and two test trials. All trials were recorded using a video camera by an evaluator at the station. As each child performed the skill, their personal ID number (assigned prior to testing) was spoken into the camera. This ensured accuracy when assigning scores to each child's performance. This process was repeated for each of the 12 FMS.

Scoring Protocol

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

Inter- and intra-rater reliability was established between a research practitioner with extensive experience using the TGMD-2 and the two principal researchers conducting the video analysis. Inter- and intra-observer agreements were calculated

for 10% of the sample, using the equation (agreements/[agreements + disagreements]) × 100. The inter- and intra-reliability scores across the 12 FMS ranged from 86–99% agreement, all of which are greater than the recommended 85% threshold required to demonstrate reliability (Thomas, Nelson, & Silverman, 2011).

Data Analysis

Children were divided into four sub-groups according to age and sex: 6-year-old boys, 6-year-old girls, 10-year-old boys, and 10-year-old girls. Means and standard deviations were used to summarize the data. An analysis of variance (ANOVA) was undertaken to investigate differences across total FMS scores, locomotor subset scores and object-control scores with respect to age and sex. All statistically significant results were supported with the strength of the result (i.e., effect size [small = 0.01; medium = 0.06; large = 0.14]; Cohen, 2013). Pairwise comparisons were used to further examine significant interaction and main effects. Fisher's exact tests were carried out to investigate if statistically significant differences existed across the number of FMS mastered by (i) age and (ii) sex, as well as the proportion of children achieving mastery in each FMS with respect to (i) age and (ii) sex. One sample *t*-tests were carried out to compare mean age and sex specific subset scores with those of a US reference sample included in the TGMD-2 manual (Ulrich, 2000). One sample *t*-tests were also used to compare mean GMQ scores with normative data (Ulrich, 2000). Finally, the distribution of the Irish sample across the performance categories for GMQ was compared to the distribution of the normative sample using chi-square tests for independence to investigate if statistical significant differences existed. The alpha level required for significance for all tests was set at $p < .05$.

Results

Table 1 presents anthropometric data, mean locomotor and object-control subset scores as well as mean GMQ scores, categorized by age and sex. Similar anthropometric measurements were observed for both boys and girls within each age group ($p > .05$).

Age and Sex Comparisons of FMS Subset Scores

Results of the ANOVA (which yielded similar results when clustering by school) are presented in Table 2. Analysis revealed a significant age effect for both locomotor and object-control subset scores. It was found that 10-year-old children scored higher than their younger counterparts in both locomotor (medium to large effect size) and object-control subset scores (large effect size) (Table 2).

A significant main effect for sex was also found, with girls scoring higher than boys in locomotor score (small effect size) while boys scored significantly higher than girls in object-control score (large effect size) (Table 2).

No significant interaction effect was found for locomotor score. However, results revealed a significant interaction between age and sex for object-control scores (Table 2). Both 10-year-old boys and 10-year-old girls scored significantly

Table 1 Characteristics, Mean Subset Scores, and GMQ Scores of the Study Sample ($M \pm SD$)

	6-year-olds		10-year-olds	
	Boys	Girls	Boys	Girls
N	52	50	58	43
Age (years)	5.9 ± 0.9	6.0 ± 0.4	10.0 ± 0.4	9.8 ± 0.4
Height (cm)	116.0 ± 4.9	115.1 ± 5.8	140.6 ± 4.9	140.2 ± 6.3
Mass (kg)	21.7 ± 3.3	21.1 ± 2.8	35.7 ± 6.9	35.9 ± 7.3
Body Mass Index (BMI)	16.0 ± 1.6	15.9 ± 1.6	17.9 ± 2.5	18.1 ± 2.9
Overweight/Obese (%)	7.8	8.2	15.5	23.8
Locomotor Score (range: 0–48)	37.6 ± 4.2	40.3 ± 3.8	41.2 ± 3.5	41.9 ± 4.0
Object-Control Score (range: 0–48)	32.0 ± 4.9	26.0 ± 4.8	40.3 ± 3.5	37.4 ± 4.3
GMQ (range: 46–160)	97.7 ± 7.2	100.9 ± 10.3	87.5 ± 9.0	92.3 ± 9.3

Table 2 Main and Interaction Effects for Age and Sex

	F	p	Effect Size	F^*	p^*	Effect Size*
Main Effects						
Age						
Locomotor Score	22.200	<.001	0.100	22.860	<.001	0.105
Object-Control Score	257.787	<.001	0.564	267.337	<.001	0.578
Sex						
Locomotor Score	9.662	.002	0.046	4.398	.01	0.063
Object-Control Score	51.967	<.001	0.207	20.683	<.001	0.241
Interaction Effects						
Locomotor Score	3.145	.08	0.016	2.355	.07	0.035
Object-Control Score	6.354	.01	0.031	4.098	.01	0.059

*Account for clustering by school.

higher than their 6-year-old counterparts in object-control subset score ($p < .05$). Also, among both 6-year-old and the 10-year-old cohorts, boys scored significantly higher than girls in object-control score ($p < .05$).

Mastery Levels Across Age and Sex

No child demonstrated mastery across all 12 FMS, with only one child (girl, 10 years) achieving mastery across 10 FMS. One girl (10 years) achieved mastery in all 6 locomotor skills while one boy (10 years) achieved mastery in all six object-control skills. No 6-year-old child achieved mastery in more than six FMS. All children did achieve mastery in at least one of the 12 FMS. Fisher's exact tests between FMS and age revealed a clear trend for higher levels of mastery in multiple

skills (two or more skills) among 10-year-old children compared to the 6-year-old children, with a significantly larger proportion of 10-year-olds achieving mastery in 2, 3, 4, 5, 6, 7, and 8 of the skills when compared to their younger counterparts ($p < .05$; see Figure 1). Fisher's exact tests between FMS mastery and sex, revealed that there was no significant difference in the number of skills mastered by boys and girls.

Locomotor Skills

Mastery levels (%) were highest in the run for both 6- (80.4%) and 10-year-olds (77.2%), while the jump was the locomotor skill in which mastery levels were the lowest for both cohorts (10.8 and 13.9% respectively; Table 3). Analysis revealed significant differences in the mastery of two locomotor skills (gallop and hop; $p < .05$). For the gallop (62.4% of 10-year-olds *vs.* 43.1% of 6-year-olds; $p < .05$, Fisher's exact test) and the hop (36.6% of 10-year-olds *vs.* 19.9% of 6-year-olds; $p < .05$, Fisher's exact test), 10-year-old children had significantly higher levels of mastery compared to 6-year-old children.

Mastery levels (%) were highest in the run for both boys (87.1%) and girls (71.8%), while the jump was the locomotor skill with the lowest levels of mastery for both sexes (11.8% for boys and 12.9% for girls; Table 3). A Fisher's exact test revealed that a larger percentage of girls achieved mastery in the run ($p < .05$) when compared to boys.

Object-Control Skills

The kick was the object-control skill with highest mastery levels among both 6- and 10-year-olds with 39.2% and 82.2% demonstrating mastery of this skill,

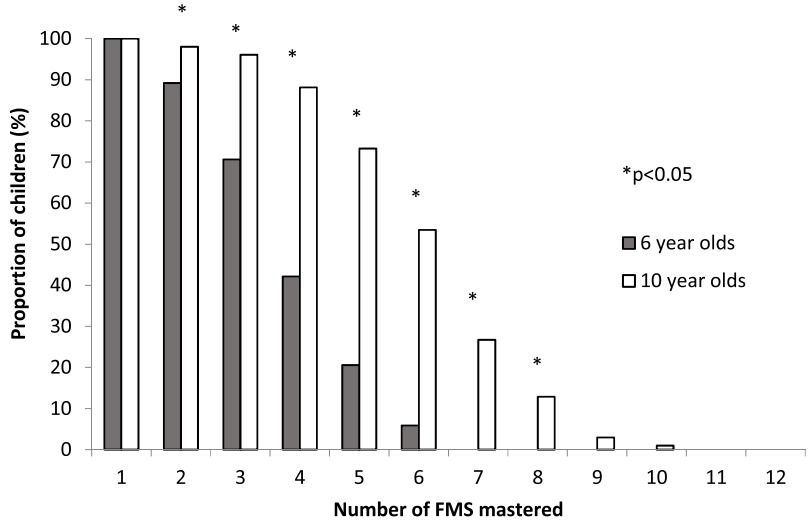

Figure 1 — Number of FMS mastered by age category.

Table 3 Percentage Achieving Mastery in Individual FMS by Age and Sex

FMS	Boys (% Mastery)	Girls (% Mastery)	*p*	6-year-olds (% Mastery)	10-year-olds (% Mastery)	*p*
Locomotor						
Run	71.8	87.1	.01	80.4	77.2	.61
Gallop	48.2	58.1	.20	43.1	62.4	.01
Hop	24.5	32.3	.27	19.6	36.6	.01
Slide	40	48.4	.26	38.2	49.5	.12
Leap	51.8	65.6	.06	54.9	61.4	.39
Jump	11.8	12.9	.83	10.8	13.9	.53
Object-Control						
Kick	77.3	40.9	<.001	39.2	82.2	<.001
Dribble	22.7	28	.42	0	50.5	<.001
Catch	25.5	18.3	.24	5.9	38.6	<.001
Strike	18.2	21.5	.60	18.6	20.8	.73
Throw	41.8	18.3	<.001	16.7	45.5	<.001
Roll	12.7	1.1	.002	1	13.9	<.001

respectively (Table 3). The dribble was the object-control skill with the lowest levels of mastery among 6-year-olds with no child of this age achieving mastery. The roll was the skill that the 10-year-olds were least proficient at with 13.9% demonstrating mastery. In five of the six object-control skills (kick, dribble, catch, throw, and roll), a significantly greater proportion of 10-year-olds achieved mastery than the 6-year-olds ($p < .05$, Fisher exact tests; Table 3).

Mastery levels were highest in the kick for both boys (77.3%) and girls (40.9%; Table 3). The object-control skill with the lowest mastery levels among this cohort was the roll, with 12.7% of boys and 1.1% of girls proficient. In three of the six object-control skills (the kick, throw, and roll), a greater proportion of boys achieved mastery, when compared to girls ($p < .05$, Fisher's exact tests). No significant differences were found between boys and girls for the dribble, catch, or strike.

Comparison With US Normative Sample

Figures 2 and 3 compare the mean locomotor and object-control subset score of the four groups in the current study with the age and sex matched counterparts from the US reference sample.

For locomotor score, both 6-year-old boys ($t = -2.379$, $p = .02$) and 10-year-old boys ($t = -4.051$, $p < .001$) scored significantly lower than the US boys of similar ages. In contrast, 6-year-old girls demonstrated significantly superior locomotor proficiency compared to the normative data from US girls ($t = 4.241$, $p < .001$), while no difference existed between the cohorts of 10-year-old girls ($t = -1.816$, $p = .08$).

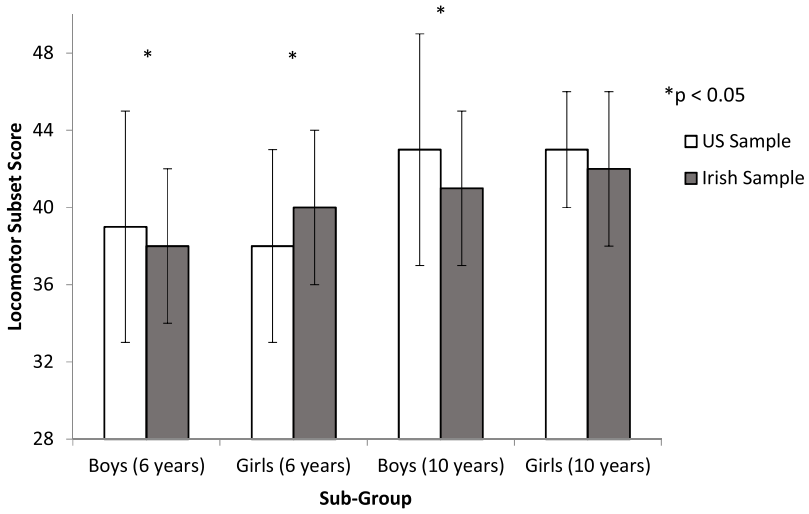

Figure 2 — Comparison of locomotor subset scores between the Irish sample and US normative sample, by age and sex.

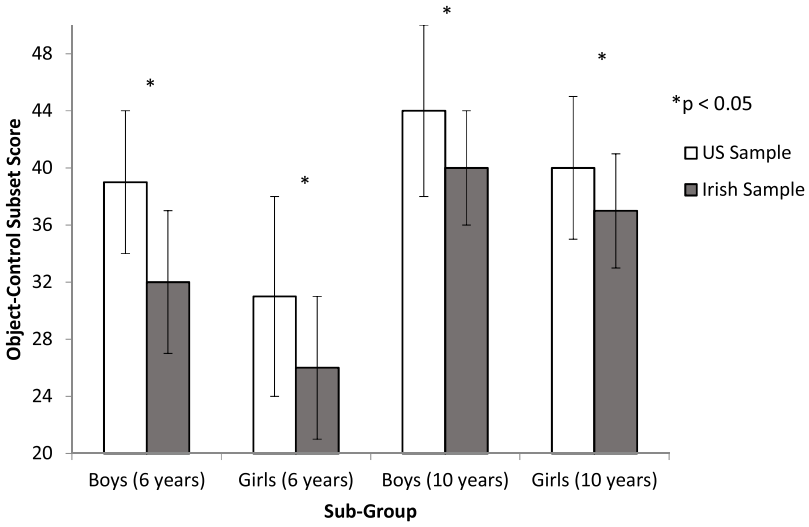

Figure 3 — Comparison of object-control subset scores between the Irish sample and US normative sample, by age and sex.

For object-control, significantly lower scores were found between all four groups compared to normative data from US children of similar age and sex. Significantly lower scores were found for 6-year-old boys ($t = -10.403$, $p < .001$), 6-year-old girls (−7.369, $p < .001$), 10-year-old boys (−8157, $p < .001$), and 10-year-old girls (−3.973, $p < .001$).

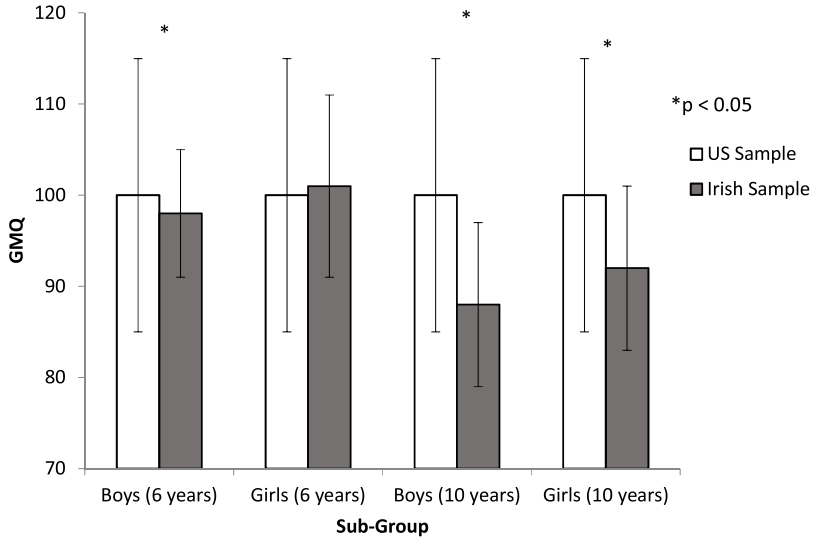

Figure 4 — Comparison of GMQ scores between the Irish sample and US normative sample, by age and sex.

When GMQ scores for the four groups were compared with the mean GMQ of the US sample (Figure 4), it was found that the 6-year-old boys scored significantly lower than the US norms ($t = -2.305$, $p = .03$), while no difference existed between 6-year-old girls and the US norms ($t = 0.621$, $p = .54$). Among the older cohort, significantly lower GMQ scores were found for both boys ($t = -10.558$, $p < .001$) and girls ($t = -5.441$, $p < .001$) compared with the reference sample.

Figure 5 shows a comparison of the distribution of the Irish sample with the US reference sample, across the seven performance categories as classified according to the TGMD-2 manual (Ulrich, 2000). Chi-square tests for independence revealed significant differences when we compared the distribution of the Irish sample across the categories with the distribution of US sample. At the lower end of the category scale, no significant differences existed across the very poor category or poor category. However there was a significantly greater proportion of the Irish children in the below average category than the US norms (chi-square = 5.364, $p = .02$, Cramer's V = 0.062). Similarly, a greater proportion of the Irish sample were classified as average compared to the US normative sample (chi-square = 12.776, $p < .001$, Cramer's V = 0.095). In contrast, at the upper end of the category scale, a significantly lower proportion of Irish children were classified in the above average (chi-square = 7.419, $p < .001$, Cramer's V = 0.111), superior (chi-square = 11.976, $p = .001$, Cramer's V = 0.096), and very superior (chi-square = 4.801, $p = .03$, Cramer's V = 0.058) categories than the normative sample.

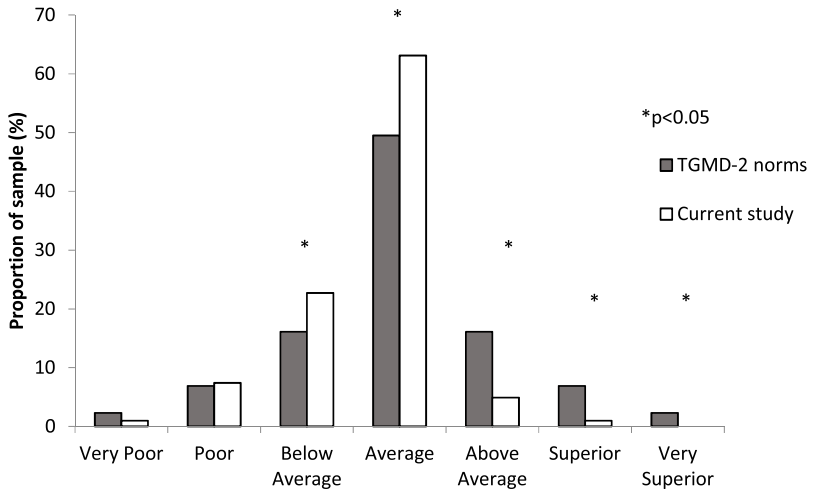

Figure 5 — Distribution of GMQ score across TGMD-2 performance categories for Irish sample and US normative sample.

Discussion

Age Comparisons of FMS Subset Scores

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

In the six locomotor skills, a significantly greater proportion of 10-year-olds achieved mastery in the gallop and hop in comparison to their younger counterparts. In these two skills, the superior co-ordination and leg strength acquired with maturation by the older cohort may also have resulted in greater performances in contrast to the 6-year-olds.

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

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

The greater FMS levels of the older cohort also results, in part, from natural maturation including physical growth and greater strength relative to their body mass (Cohen et al., 2015) as well as the maturation of the nervous system (Charlesworth, 2016) enabling greater co-ordination and control of limbs.

Sex-Related Comparisons of FMS Subset Scores

When subset scores were compared among boys and girls, it was found that girls outperformed the boys in locomotor score, independent of age. This is similar to previous studies (Barnett et al., 2009; Hardy et al., 2010) that reported gender differences among 4- to 5-year-olds (Hardy et al., 2010) and 8- to 10-year-old rural Australian children (Barnett et al., 2009). In the individual locomotor skills, mastery levels were higher among girls than boys in all six skills, with a significant difference in the run ($p = .01$). The greater locomotor proficiency among girls has been previously accounted for by the types of activities that girls are more likely to participate in such as dance and gymnastics, which have a greater emphasis on locomotor skills (Booth et al., 1999, 2006), a trend that is also evident in an Irish context (Woods, Moyna, Quinlan, Tannehill, & Walsh, 2010). Further analysis revealed no significant difference in locomotor score between 10-year-old girls and boys which is similar to many studies worldwide (Bakhtiar, 2014; Kordi et al., 2012; van Beurden et al., 2002). This may be explained by the incorporation of the locomotor skills in a vast majority of sports and activities which children participate in during free play, physical education and sports.

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

The superiority of boys in object-control skills have been rationalized by the fact that boys participate in more sports/activities that involve object manipulation such as soccer and rugby than girls (Booth et al., 2006), a trend that is also evident among Irish primary school children with soccer, Gaelic Football, hurling, rugby, and basketball among the most popular male sports (Williams et al., 2009; Woods et al., 2010). All of these sports/activities allow for greater exposure to, and practice of, these skills. In contrast, dance and swimming are among the most popular activities engaged in by girls in addition to drama and ballet (Williams et al., 2009;

Woods et al., 2010); none of which focus on object-control skills. Furthermore, Irish boys have been reported to participate in extra-curricular activity more frequently than girls according to the CSPPA (The Children's Sport Participation and Physical Activity) study and this additional time is spent playing ball sports (Woods et al., 2010) which exposes them to further instruction, feedback than their female counterparts.

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

FMS Proficiency—A Global Comparison

FMS proficiency levels of Irish primary school children were found to be similar to levels reported worldwide (Bardid et al., 2016; Bellows et al., 2013; Burrows et al., 2014; Cliff et al., 2009; Spessato et al., 2013; Ulrich, 2000). Mean GMQ score for 6-year-olds (boys and girls) and 10-year-old girls classified the FMS proficiency of these sub-groups in the average category, according to the TGMD-2 (ranging from 90–110) (Ulrich, 2000). This is similar to findings by Bardid et al. (2016) in a study of 3- to 8-year-old Portuguese children ($n = 1614$) in which average scores were recorded for the 3-, 4-, 5-, and 6-year-old cohorts, respectively. This was also found among 3- to 5-year-old children in Colorado (Bellows et al., 2013) and preschool girls in Australia (Cliff et al., 2009). In contrast, the 10-year-old boys in the current study scored below average (GMQ ranging 80–89) relative to Ulrich's normative dataset (Ulrich, 2000), similar to FMS proficiency among 3- to 10-year-old Brazilian children ($n = 1248$) (Spessato et al., 2013), preschool boys in Australia (Lubans et al., 2010), and 6- to 10-year-old Canadian children (Burrows et al., 2014), who also scored below TGMD-2 norms.

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

In the current study, the locomotor skill with the highest mastery levels was the run. Similar findings were found among US, New Zealand, and Brazilian children (Mitchell et al., 2013; Ulrich, 2000; Valentini et al., 2016). The jump was the locomotor skill with the lowest mastery levels in our sample, followed by the hop. Interestingly, the jump was also reported to be the least proficient locomotor skill by Mitchell et al. (2013), while the both the jump and hop were the locomotor skills

with the lowest levels of mastery reported by Valentini et al. (2016). This may be explained by the complexity of these two skills as both involve a combination of physical challenge, including strength for take-off, postural control, as well as co-ordination and balance during flight and landing (Haibach, Reid, & Collier, 2011).

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

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

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

Many factors contribute to the low FMS levels exhibited among Irish primary school children relative to the US norms. These include low physical activity levels, with only 19% of children reaching the recommended 60 minutes of moderate-to-vigorous physical activity daily (Woods et al., 2010). Furthermore, the time spent in physical education (PE) in Irish primary schools is low. While the recommended level of weekly PE is 60 minutes, it has been reported that only 46 minutes per week PE is received by Irish primary school children (European Commission/EACEA/Eurydice, 2013). It has also been reported that Ireland spends less time in physical education in primary schools than all other EU countries (European Commission/EACEA/Eurydice, 2013). In contrast, US children (5- to 10-year-olds) are recommended to receive a minimum of 150 minutes instructional PE (National Association for Sport and Physical Activity, 1997).

Although data collection was conducted in 1997–1998, US children, at that time, were recommended to receive daily physical education classes and it was found that elementary children received 50–200 minutes physical education weekly (National Association for Sport and Physical Activity, 1997). Furthermore, this physical education was delivered by a physical education specialist and/with the classroom teacher (National Association for Sport and Physical Activity, 1997) in contrast to the classroom teacher only in Ireland. Considering the reported low levels of both physical activity and PE participation among Irish primary school children (which is much lower compared to other European countries and the US), it is reasonable to suggest that the time devoted to FMS instruction and practice in Ireland is insufficient and it deserves greater prominence in the primary school curriculum.

Implications

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

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

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

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

To bridge sex-related differences that exist in both locomotor and object-control proficiency, it is important that boys and girls receive equal encouragement, instruction, and opportunities to practice skills from both sub categories during PE, extra-curricular activity, and free play from teachers, parents, and peers (Spessato et al., 2013). As children have the potential to master FMS by the age of five to seven years (Gallahue & Ozmun, 2006) and have been shown to improve FMS greatly at a young age (Mitchell et al., 2013), it is important that all approaches are introduced as early as possible in primary school-aged children.

Low FMS levels revealed in the current study and the existing high levels of overweight/obesity in Ireland based on international comparisons (Webber et al., 2014) highlight the need for FMS interventions in Irish primary schools to promote

a favorable body composition and facilitate physical activity among many other associated health benefits. Such interventions may potentially combat the rise in obesity predicted for Ireland (Webber et al., 2014).

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

Limitations

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

Acknowledgments

The primary schools including teachers, principals, other staff members and students from the participating schools are thanked for their support, contribution and co-operation. The authors declare that the results of the current study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The authors declare there is no conflict of interest.

References

Bakhtiar, S. (2014). Fundamental motor skill among 6-year-old children in Padang, West Sumatera, Indonesia. *Asian Social Science, 10*(5), 155–158. doi:10.5539/ass.v10n5p155

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

Barnett, L.M., Stodden, D., Cohen, K.E., Smith, J.J., Lubans, D.R., Lenoir, M., ... Morgan, P.J. (2016). Fundamental movement skills: An important focus. *Journal of Teaching in Physical Education, 35*(3), 219–225. doi:10.1123/jtpe.2014-0209

Barnett, L.M., Van Beurden, E., Morgan, P.J., Brooks, L.O., & Beard, J.R. (2008). Does childhood motor skill proficiency predict adolescent fitness? *Medicine and Science in Sports and Exercise, 40*(12), 2137–2144. PubMed ID: 18981934 doi:10.1249/MSS.0b013e31818160d3

Barnett, L.M., Van Beurden, E., Morgan, P.J., Brooks, L.O., & Beard, J.R. (2009). Childhood motor skill proficiency as a predictor of adolescent physical activity. *Journal of Adolescent Health, 44*(3), 252–259. PubMed ID: 19237111 doi:10.1016/j.jadohealth.2008.07.004

Bellows, L.L., Davies, P.L., Anderson, J., & Kennedy, C. (2013). Effectiveness of a physical activity intervention for head start preschoolers: A randomized intervention study. *American Journal of Occupational Therapy, 67*(1), 28–36. PubMed ID: 23245780 doi:10.5014/ajot.2013.005777

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

Booth, M.L., Okely, T., McLellan, L., Phongsavan, P., Macaskill, P., Patterson, J., ... Holland, B. (1999). Mastery of fundamental movement skills among New South Wales school students: Prevalence and sociodemographic distribution. *Journal of Science and Medicine in Sport, 2*(2), 93–105. PubMed ID: 10476973 doi:10.1016/S1440-2440(99)80189-3

Breslin, G., Murphy, M., McKee, D., Delaney, B., & Dempster, M. (2012). The effect of teachers trained in a fundamental movement skills programme on children's self-perceptions and motor competence. *European Physical Education Review, 18*, 114–126. doi:10.1177/1356336X11430657

Bryant, E.S., Duncan, M.J., & Birch, S.L. (2014). Fundamental movement skills and weight status in British primary school children. *European Journal of Sport Science, 14*(7), 730–736. PubMed ID: 24354691 doi:10.1080/17461391.2013.870232

Burrows, E.J., Keats, M.R., & Kolen, A.M. (2014). Contributions of after school programs to the development of fundamental movement skills in children. *International Journal of Exercise Science, 7*(3), 236–249. PubMed ID: 27293501

Cattuzzo, M.T., dos Santos Henrique, R., Ré, A.H.N., de Oliveira, I.S., Melo, B.M., de Sousa Moura, M., ... Stodden, D. (2016). Motor competence and health related physical fitness in youth: A systematic review. *Journal of Science and Medicine in Sport, 19*, 123–129. PubMed ID: 25554655 doi:10.1016/j.jsams.2014.12.004

Charlesworth, R. (2016). *Understanding child development* (10th ed.). Boston, MA: Cengage Learning.

Cliff, D.P., Okely, A.D., Smith, L.M., & McKeen, K. (2009). Relationships between fundamental movement skills and objectively measured physical activity in preschool children. *Pediatric Exercise Science, 21*(4), 436–449. PubMed ID: 20128363 doi:10.1123/pes.21.4.436

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Cohen, K.E., Morgan, P.J., Plotnikoff, R.C., Callister, R., & Lubans, D.R. (2015). Physical activity and skills intervention: Scores cluster randomized controlled trial. *Medicine and Science in Sports and Exercise, 47*(4), 765–774. PubMed ID: 25051389 doi:10.1249/MSS.0000000000000452

Cole, T.J., Bellizzi, M.C., Flegal, K.M., & Dietz, W.H. (2000). Establishing a standard definition for child overweight and obesity worldwide: International survey. *British*

Medical Journal, 320, 1240–1243. PubMed ID: 10797032 doi:10.1136/bmj.320.7244.1240

Coppinger, T., Lacey, S., O'Neill, C., & Burns, C. (2016). "Project Spraoi": A randomized control trial to improve nutrition and physical activity in school children. *Contemporary Clinical Trials Communications, 3*, 94–101. doi:10.1016/j.conctc.2016.04.007

Education in New Zealand. (2015). Education in New Zealand an insiders guide to studying abroad in New Zealand. Retrieved March 9, 2016, from http://www.education-newzealand.org/sports/

European Commission/EACEA/Eurydice. (2013). *Physical education and sport at school in Europe eurydice report*. Luxembourg, Luxembourg: Education, Audiovisual and Culture Executive Agency, European Commission.

Freitas, D.L., Lausen, B., Maia, J.A., Lefevre, J., Gouveia, É.R., Thomis, M., … Malina, R.M. (2015). Skeletal maturation, fundamental motor skills and motor coordination in children 7–10 years. *Journal of Sports Sciences, 33*(9), 924–934. PubMed ID: 25649360 doi:10.1080/02640414.2014.977935

Gallahue, D.L., & Ozmun, J.C. (2006). *Understanding motor development: Infants, children, adolescents, adults* (6th ed.). New York, NY: McGraw-Hill.

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

Haapala, E.A. (2013). Cardiorespiratory fitness and motor skills in relation to cognition and academic performance in children: A review. *Journal of Human Kinetics, 36*(1), 5–189. doi:10.2478/hukin-2013-0006

Haibach, P.S., Reid, G., & Collier, D.H. (2011). *Motor learning and development*. Champaign, IL: Human Kinetics.

Hardy, L.L., King, L., Farrell, L., Macniven, R., & Howlett, S. (2010). Fundamental movement skills among Australian preschool children. *Journal of Science and Medicine in Sport, 13*(5), 503–508. PubMed ID: 19850520 doi:10.1016/j.jsams.2009.05.010

Holfelder, B., & Schott, N. (2014). Relationship of fundamental movement skills and physical activity in children and adolescents: A systematic review. *Psychol Sport Exerc, 15*(4), 382–391. doi:10.1016/j.psychsport.2014.03.005

Khodaverdi, F., & Bahram, A. (2015). Relationship between motor skill competence and physical activity in girls. *Annals of Applied Sport Science, 3*(2), 43–50. doi:10.18869/acadpub.aassjournal.3.2.43

Kordi, R., Nourian, R., Ghayour, M., Kordi, M., & Younesian, A. (2012). Development and evaluation of a basic physical and sports activity program for preschool children in nursery schools in Iran: An interventional study. *Iranian Journal of Pediatrics, 22*(3), 357–363. PubMed ID: 23400235

Logan, S.W., Robinson, L.E., Wilson, A.E., & Lucas, W.A. (2011). Getting the fundamentals of movement: A meta-analysis of the effectiveness of motor skill interventions in children. *Child: Care, Health and Development, 38*(3), 305–315. doi:10.1111/j.1365-2214.2011.01307.x

Lubans, D.R., Morgan, P.J., Cliff, D.P., Barnett, L.M., & Okely, A.D. (2010). Fundamental movement skills in children and adolescents: Review of associated health benefits. *Sports Medicine, 40*(12), 1019–1035. PubMed ID: 21058749 doi:10.2165/11536850-000000000-00000

Malina, R.M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity*. Champaign, IL: Human Kinetics.

Mitchell, B., Mclennan, S., Latimer, K., Graham, D., Gilmore, J., & Rush, E. (2013). Improvement of fundamental movement skills through support and mentorship of class room teachers. *Obesity Research & Clinical Practice, 7*(3), e230–e234. PubMed ID: 23697592 doi:10.1016/j.orcp.2011.11.002

Morgan, P.J., & Hansen, V. (2008). Classroom teachers' perceptions of the impact of barriers to teaching physical education on the quality of physical education programs. *Research Quarterly for Exercise and Sport, 79*(4), 506–516. PubMed ID: 19177952 doi:10.1080/02701367.2008.10599517

National Association for Sport and Physical Activity. (1997). *Shape of the nation report*. Virginia.

O'Brien, W., Belton, S., & Issartel, J. (2016). Fundamental movement skill proficiency amongst adolescent youth. *Physical Education and Sport Pedagogy, 21*(6), 557–571. doi:10.1080/17408989.2015.1017451

Pang, A.W., & Fong, D.T. (2009). Fundamental motor skill proficiency of Hong Kong children aged 6–9 years. *Research in Sports Medicine, 17*, 125–144. PubMed ID: 19731174 doi:10.1080/15438620902897516

Spessato, B.C., Gabbard, C., Valentini, N., & Rudisill, M. (2013). Gender differences in Brazilian children's fundamental movement skill performance. *Early Child Development and Care, 183*(7), 916–923. doi:10.1080/03004430.2012.689761

Thomas, J.R., & French, K.E. (1985). Gender differences across age in motor performance: A meta-analysis. *Psychological Bulletin, 98*(2), 260–282. doi:10.1037/0033-2909.98.2.260

Thomas, J.R., Nelson, J.K., & Silverman, S.J. (2011). *Research methods in physical activity* (6th ed.). Champaign, IL: Human Kinetics.

Tremblay, M.S. (2014). 2014 Global summit on the physical activity of children. *Journal of Physical Activity and Health, 11*(Suppl. 1), S1–S2. doi:10.1123/jpah.2014-0182

Ulrich, D.A. (2000). *TGMD-2 test of gross motor development* (2nd ed.). Austin, TX: Pro-Ed Publishers.

Valentini, N.C., Logan, S.W., Spessato, B.C., de Souza, M.S., Pereira, K.G., & Rudisill, M.E. (2016). Fundamental motor skills across childhood: Age, sex, and competence outcomes of Brazilian children. *Journal of Motor Learning and Development, 4*(1), 16–36. doi:10.1123/jmld.2015-0021

van Beurden, E., Barnett, L.M., & Dietrich, U.C. (2002). Fundamental movement skills – How do primary school children perform? The "Move it Groove it" program in rural Australia. *Journal of Science and Medicine in Sport, 5*(3), 244–252. PubMed ID: 12413042 doi:10.1016/S1440-2440(02)80010-X

Wallerson, R. (2014). Youth participation weakens in Basketball, Football, Baseball, Soccer. *The Wall Street Journal*. Retrieved from https://www.wsj.com/articles/youth-participation-weakens-in-basketball-football-baseball-soccer-1391138849

Webber, L., Divajeva, D., Marsh, T., McPherson, K., Brown, M., Galea, G., & Breda, J. (2014). The future burden of obesity-related diseases in the 53 World Health Organization European-region countries and the impact of effective interventions: A modelling study. *British Medical Journal, 4*(7), e004787. doi:10.1136/bmjopen-2014-004787

Williams, J., Greene, S., Doyle, E., Harris, E., Layte, R., McCoy, S., ... Thornton, M. (2009). *Growing up in Ireland-national longitudinal study of children: The lives of 9-year-olds*. Dublin, IE: The Stationery Office.

Woods, C., Moyna, N., Quinlan, A., Tannehill, D., & Walsh, J. (2010). *The Children's Sport Participation and Physical Activity Study (CSPPA Study)*. Research Report No. 1. Dublin, IE: School of Health and Human Performance, Dublin City University and the Irish Sports Council, Dublin, Ireland.