scientific reports

OPEN

Comparative analysis of three process-oriented assessment tools for identifying fundamental motor skills proficiency in children

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The current study aimed to examine discrepancies between three different process-oriented tools in assessing the same fundamental movement skills in primary school children. A total of 120 children aged 6–12 years (mean age: 9.3 ± 1.9 years) were evaluated on 6 skills (run, leap, kick, over-hand throw, catch, and two-hand strike) common to the Test of Gross Motor Development (TGMD) 2nd or 3rd edition, Get Skilled Get Active (GSGA), and Fundamental Motor Skills Assessment (FMSA). Differences were analysed using standardised scores (raw score divided by the number of performance criteria of each skill) and the prevalence of advanced skills (i.e., correct execution of all or all but one performance criteria). The main results showed large correlations between tools, but significant differences ($p < 0.05$) in standardised scores of each assessment tool across all skills. The TGMD classified a significantly higher percentage of children as having advanced skills in running, leaping, kicking, and catching compared to the GSGA and FMSA. These findings suggest that tools with fewer performance criteria for each skill may be less rigorous than more detailed assessments such as the GSGA and FMSA, emphasising the importance of standardising scoring procedures and developing clearer, universally accepted criteria across FMS assessments.

Keywords Gross motor skills, Motor competence, Proficiency, Measurement, Childhood.

Fundamental movement skills (FMS) are defined as an organised sequence of movement patterns that require the integration of two or more body segments[1] and are generally categorised into locomotor (e.g., running or jumping), manipulative (e.g., catching or throwing), and stability (e.g., balance or turning) skills[1,2]. FMS develop through a defined and observable process from immaturity to proficiency[1] and are considered the building blocks of more advanced and complex movement patterns required to participate in games, sports, or other specific physical activities[2]. Current scientific evidence underscores the crucial role of FMS in the holistic development of children[3], demonstrating that proficiency in these skills is positively associated with higher levels of physical activity[4] and physical fitness[5,6] during childhood and adolescence, while inversely correlated with weight status[4–6]. Research also indicates that proficiency in FMS varies significantly according to sex, age, and school year[7–9]. Males generally demonstrate higher levels of mastery in manipulative skills than females, a disparity often attributed to various socio-cultural factors[7–9]. Additionally, children tend to show marked improvements in FMS proficiency as they progress through school, particularly up to the age of ten[7]. This trend highlights the importance of age-related maturation and targeted educational interventions in fostering skill acquisition.

Given the importance of FMS, numerous assessment tools have been developed and are widely used for clinical, educational, and research purposes[10,11]. In this sense, FMS testing is crucial for identifying children with motor skill deficiencies, describing and comparing motor proficiency levels across different populations, and guiding the design and evaluation of tailored interventions[11–13]. Typically, these assessment tools are categorised into product-oriented and process-oriented measures[2]. Product-oriented measures focus on the outcomes of skill execution (e.g., throw velocity or jump distance), whereas process-oriented measures evaluate the quality of

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movement patterns during skill execution (e.g., demonstration of specific behavioural components of a skill)[2]. Current research indicates that correlations between process- and product-oriented assessments vary from weak to strong, depending on the specific skill and the age of children being assessed[14,15]. However, the process-oriented approach is particularly valuable for providing qualitative insights into children's motor competence that can be used to design and plan interventions[12].

Recent systematic reviews[2,10,16] indicate that among process-oriented assessment tools, the Test of Gross Motor Development (TGMD) and its variants, TGMD-2[17] and TGMD-3[18], are probably the most commonly used tools for assessing FMS proficiency, along with the Get Skilled Get Active (GSGA) resource[19] and the Fundamental Motor Skills Assessment (FMSA) manual developed by the Department of Education of Victoria[20]. Nevertheless, the absence of a universally accepted "gold standard" for assessing FMS across different cultures, regions, and age groups poses substantial challenges in tracking motor competence over time and comparing results across studies[13]. The saturation of available assessment tools, each with different criteria, administration procedures, and scoring methods[21], further complicates the selection of the most appropriate tool to accurately identify children with FMS developmental difficulties[10]. For instance, Logan et al.[15] reported significant differences between the TGMD-2 and GSGA when evaluating the mastery of common FMS, such as hopping and overhand throwing, within the same group of children. Such differences could underline the need for more standardized and cross-culturally valid tools to ensure consistent measurement and diagnosis of FMS proficiency.

To the best of the authors' knowledge, no prior studies have comprehensively examined differences in children's proficiency across a broad range of FMS using various process-oriented assessment tools. Existing research, such as the study by Logan et al.[15], has only focused on a limited set of three skills. Furthermore, their study also lacks detailed information on proficiency at the component level of each FMS, which may be valuable for researchers and educators to better understand the differences between assessment tools[22]. This gap in the literature highlights the need for a more thorough investigation. Therefore, the primary aim of the current study was to compare three different process-oriented batteries (TGMD, GSGA, and FMSA) to identify discrepancies in the results obtained when assessing the same FMS with each tool in primary school-aged children. By examining these differences across a broader range of FMS, this study aimed to provide a more holistic understanding of the variability between these tools, helping to inform more standardized approaches to FMS assessment. In addition, a secondary endpoint was to analyse such differences in FMS proficiency according to sex, school year, and at the behavioural component level. Based on previous research[15], this study hypothesised that proficiency levels for a specific skill would be higher when using an assessment tool with fewer performance criteria.

Methods

Participants

One hundred and twenty children (60 males and 60 females) aged between 6 and 12 years (age: 9.3 ± 1.9 years; height: 135.2 ± 13.3 cm; body mass: 35.5 ± 12.0 kg) participated in this study. Participants were enrolled in four different public primary schools in Galicia, Spain. Children were classified into three groups according to their school year: grades 1–2 (n = 40; age: 7.1 ± 0.6 years), grades 3–4 (n = 40; age: 9.3 ± 0.7 years), and grades 5–6 (n = 40; age: 11.4 ± 0.7 years). At the time of testing, none of the participants had any medical conditions that could have affected their motor performance, and all regularly attended physical education classes. The data analysed in this study were drawn from a larger research project (ALFA-MOV; PID2021-128640OB-I00), from which the specific subset was selected through stratified random sampling to address the current research questions. Stratification was based on school year and sex, with 10 males and 10 females randomly selected from each of the six school grades. An a priori power analysis was conducted using G*Power software (version 3.1.9.2, Universität Kiel, Düsseldorf, Germany)[23]. The effect size set at 0.5, assuming a type I error of 0.05, a type II error of 0.20 (80% statistical power), and a correlation among repeated measures of 0.5. This analysis indicated that a minimum of 9 children per group would be required. Prior to participation, all children and their legal guardians were informed about the aims, procedures, potential benefits, and possible risks of the study. Children gave their verbal assent and were authorised by their guardians, who signed an informed consent form. The research procedures were approved by the Local Ethics Committee of the University of Vigo (Code: 17–0320) in accordance with the Declaration of Helsinki.

Variables and procedures

Participants were evaluated during their regular physical education classes under the supervision of their respective teachers. A total of six FMS were assessed: run, leap, kick, over-hand throw, catch, and two-hand strike. These skills were selected due to their inclusion in either the TGDM-2[17] or TGMD-3[18], as well as in the GSGA[19] and FMSA[20]. Despite the discrepancies in scoring and administration procedures across these assessment tools, the procedures outlined in the TGMD-3[18] were followed to ensure consistency, in line with Logan et al.[15]. First, a researcher demonstrated each skill, followed by a practice attempt by the children to ensure their understanding of the task. Each participant then completed two trials of each skill, which were recorded on video for subsequent analysis.

FMS scores were determined by evaluating whether each child met the performance criteria established for each skill and assessment tool. Specifically, for the FMS assessed, the TGMD includes 3 to 5 performance criteria per skill, the GSGA includes 6 to 7, and the FMSA includes 5 to 8. Further details on the specific criteria are provided in Supplementary Tables S1–3. Each criterion was scored as 1 or 0, depending on its presence or absence. The results of the two trials were then summed to calculate a raw score for each skill. To account for differences in the number of performance criteria for each skill between assessment tools, a standardised score was calculated by dividing the raw score by the number of performance criteria included in the checklist of each assessment tool. In addition, the level of proficiency was analysed based on the variables of mastery, near-mastery, and advanced skills. According to Booth et al.[24], mastery was defined as the correct execution of all performance criteria associated with a given skill, while near-mastery was assigned when a child demonstrated all but one of the skill components. The classifications of mastery and near-mastery were also combined to create the variable of advanced skills[24]. Children who did not meet the criteria for achieving mastery or near-mastery were classified as having poor mastery.

Two researchers with prior training and experience analysed the FMS videos using software that enabled slow motion, replay, and both forward and backward viewing. Consistent with Bolger et al.[25], inter- and intra-rater agreement was assessed to exceed 85% between the two researchers conducting the video analysis before formal data coding. This was determined by calculating the ratio of agreements / (agreements + disagreements) × 100 to establish the percentage of agreement on 10% of the data set. The inter- and intra-reliability scores across the six FMS assessments ranged from 85 to 94% agreement.

Statistical analyses

All analyses were performed using SPSS for Windows (version 25.0. Armonk, NY: IBM Corp). The normality of each variable was checked both graphically and using the Kolmogorov-Smirnov test. Descriptive statistics are presented as mean ± standard deviation (SD). Correlations between FMS raw scores derived from each assessment tool were determined using Spearman's Rho test. The magnitude of effect for these correlation coefficients was interpreted based on the following scale[26]: trivial (< 0.10), small (0.10 to 0.29), moderate (0.30 to 0.49), large (0.50 to 0.69), very large (0.70 to 0.89), and extremely large (≥ 0.90). Repeated-measures Friedman test was used to analyse differences in standardised scores according to the assessment tool, both for the whole sample and separately by sex and school year. For pairwise comparisons, the Conover post-hoc test with Bonferroni correction was applied. Differences in the prevalence of advanced skills according to the assessment tool were analysed using Cochran's *Q* test. For all analyses, the significance level was set at $p < 0.05$.

Results

Table 1 presents the Spearman's Rho correlations between the raw scores of each assessment tool for the different FMS. All correlations were statistically significant ($p < 0.001$). Large correlations were observed between TMGD score for the run with respect to GSGA and FMSA (Rho = 0.697 and 0.662, respectively), while the correlation between GSGA and FMSA was very large. For the leap and kick, very large correlations were found between assessment tools (Rho = 0.737–0.844), except for an extremely large correlation between GSGA and FMSA scores for the kick. Regarding the over-hand throw, catch and two-hand strike, extremely large correlations were found between assessment tools (Rho = 0.922–0.972), except for a very large correlation between TGMD and GSGA scores for the catch.

Table 2 shows the raw score, standardised score, and prevalence of advanced skills for each FMS and assessment tool according to sex, while Table 3 displays these values according to school year. Overall, the results of repeated-measures Friedman tests revealed significant differences in standardised scores between assessment tools for the run ($\chi^2 = 156.14$; $p < 0.001$), leap ($\chi^2 = 61.28$; $p < 0.001$), kick ($\chi^2 = 9.80$; $p = 0.007$), over-hand throw ($\chi^2 = 139.30$; $p < 0.001$), catch ($\chi^2 = 16.43$; $p < 0.001$), and two-hand strike ($\chi^2 = 17.69$; $p < 0.001$). Children's standardised scores for the run were significantly higher in the TGMD compared to the GSGA ($p < 0.001$) and FMSA ($p < 0.001$), as well as in FMSA compared to GSGA ($p < 0.001$). Leap scores were significantly lower in the GSGA compared to the TGMD ($p < 0.001$) and FMSA ($p < 0.001$). Kick scores were significantly lower in the GSGA compared to the TGMD ($p = 0.027$). TGMD standardised scores for the over-hand throw were significantly lower than in the GSGA ($p < 0.001$) and FMSA ($p < 0.001$). Catch standardised scores were significantly higher in the GSGA compared to the TGMD ($p = 0.027$), and two-hand strike standardised scores were significantly higher in the GSGA compared to both the TGMD ($p < 0.001$) and FMSA ($p = 0.032$).

With respect to the prevalence of advanced skills, the results of the Cochran *Q* tests revealed significant differences across assessment tools for the run ($\chi^2 = 106.12$; $p < 0.001$), leap ($\chi^2 = 86.98$; $p < 0.001$), kick ($\chi^2 = 38.35$; $p < 0.001$), catch ($\chi^2 = 37.33$; $p < 0.001$), and two-hand strike ($\chi^2 = 37.33$; $p < 0.001$), but not for the over-hand throw ($\chi^2 = 1.33$; $p = 0.513$). The TGMD showed the highest prevalence of advanced skills for the run, significantly greater than both the GSGA ($p < 0.001$) and FMSA ($p < 0.001$), with FMSA also outperforming GSGA ($p < 0.001$). Similarly, for the leap, the TGMD showed the highest prevalence compared to the GSGA ($p < 0.001$) and FMSA ($p < 0.001$), with the FMSA also showing a higher prevalence compared to the GSGA ($p = 0.001$). For the kick and catch, the highest prevalence of advanced skills was observed for the TGMD compared to the GSGA ($p < 0.001$) and FMSA ($p < 0.001$). The prevalence of advanced skills for the two-hand strike was lower in the FMSA

	TGMD vs. GSGA	TGMD vs. FMSA	GSGA vs. FMSA
Run	0.697 (< 0.001)	0.662 (< 0.001)	0.842 (< 0.001)
Leap	0.760 (< 0.001)	0.737 (< 0.001)	0.828 (< 0.001)
Kick	0.844 (< 0.001)	0.816 (< 0.001)	0.974 (< 0.001)
Over-hand throw	0.972 (< 0.001)	0.922 (< 0.001)	0.966 (< 0.001)
Catch	0.811 (< 0.001)	0.923 (< 0.001)	0.943 (< 0.001)
Two-hand strike	0.946 (< 0.001)	0.923 (< 0.001)	0.958 (< 0.001)

Table 1. Spearman's Rho correlations (*p*-value) between assessment tools for each fundamental movement skill. TGMD: test of gross motor development. GSGA: get skilled get active. FMSA: fundamental motor skills assessment.

		Raw score (M ± SD)			Standardized score (M ± SD)			Advanced skills (%)		
		All	Male	Female	All	Male	Female	All	Male	Female
Run	TGMD	7.28 ± 1.18	7.28 ± 1.18	7.28 ± 1.18	91.0 ± 14.7$^{\#\ddagger}$	91.0 ± 14.7$^{\#\ddagger}$	91.0 ± 14.7$^{\#\ddagger}$	89.2$^{\#\ddagger}$	91.7$^{\#\ddagger}$	86.7$^{\#\ddagger}$
	GSGA	7.98 ± 2.55	8.02 ± 2.51	7.95 ± 2.60	66.5 ± 21.2*‡	66.8 ± 21.0*‡	66.3 ± 21.7*‡	31.7*‡	30.0*‡	33.3*‡
	FMSA	7.88 ± 1.56	8.12 ± 1.51	7.63 ± 1.59	78.7 ± 15.6$^{*\#}$	81.2 ± 15.1$^{*\#}$	76.3 ± 15.9$^{*\#}$	68.3$^{*\#}$	70.0$^{*\#}$	66.7$^{*\#}$
Leap	TGMD	4.50 ± 1.24	4.47 ± 1.28	4.53 ± 1.20	75.0 ± 20.6$^{\#}$	74.4 ± 21.4$^{\#}$	75.6 ± 20.0$^{\#}$	71.7$^{\#\ddagger}$	70.0$^{\#\ddagger}$	73.3$^{\#\ddagger}$
	GSGA	7.55 ± 2.63	7.22 ± 2.70	7.88 ± 2.55	62.9 ± 22.0*‡	60.1 ± 22.5*‡	65.7 ± 21.2*‡	22.5*‡	20.0*	25.0*‡
	FMSA	7.35 ± 1.86	7.08 ± 1.93	7.62 ± 1.76	73.5 ± 18.6$^{\#}$	70.8 ± 19.3$^{\#}$	76.2 ± 17.6$^{\#}$	41.7$^{*\#}$	35.0*	48.3$^{*\#}$
Kick	TGMD	6.19 ± 1.73	6.77 ± 1.43	5.62 ± 1.82	77.4 ± 21.6$^{\#}$	84.6 ± 17.9	70.2 ± 22.8‡	55.0$^{\#\ddagger}$	66.7$^{\#}$	43.3$^{\#\ddagger}$
	GSGA	8.94 ± 2.43	9.97 ± 2.02	7.92 ± 2.39	74.5 ± 20.2*	83.1 ± 16.8	66.0 ± 19.9	37.5*	55.0*	20.0*
	FMSA	10.3 ± 3.14	11.7 ± 2.59	8.83 ± 3.02	73.3 ± 22.4	83.5 ± 18.5	63.1 ± 21.5*	37.5*	58.3	16.7*
Over-hand throw	TGMD	4.42 ± 1.98	5.38 ± 1.55	3.47 ± 1.91	55.3 ± 24.8$^{\#\ddagger}$	67.3 ± 19.4$^{\#\ddagger}$	43.3 ± 23.9$^{\#\ddagger}$	32.5	45.0	20.0
	GSGA	7.67 ± 2.68	9.02 ± 1.94	6.33 ± 2.65	64.0 ± 22.3*	75.1 ± 16.2*	52.8 ± 22.1*	30.8	43.3	18.3
	FMSA	7.55 ± 2.57	8.83 ± 1.78	6.27 ± 2.62	62.9 ± 21.4*	73.6 ± 14.8*	52.2 ± 21.8*	30.8	41.7	20.0
Catch	TGMD	4.58 ± 1.61	4.62 ± 1.54	4.53 ± 1.68	76.3 ± 26.8$^{\#}$	76.9 ± 25.7$^{\#}$	75.6 ± 28.0	70.8$^{\#\ddagger}$	73.3$^{\#\ddagger}$	68.3‡
	GSGA	9.68 ± 2.60	9.80 ± 2.56	9.57 ± 2.64	80.7 ± 21.6*	81.7 ± 21.4*	79.7 ± 22.0	57.5*	56.7*	58.3
	FMSA	9.28 ± 2.83	9.43 ± 2.76	9.13 ± 2.91	77.4 ± 23.6	78.6 ± 23.0	76.1 ± 24.2	50.8*	51.7*	50.0*
Two-hand strike	TGMD	7.26 ± 2.49	8.05 ± 2.31	6.47 ± 2.42	72.6 ± 24.9$^{\#}$	80.5 ± 23.1	64.7 ± 24.2$^{\#}$	51.7‡	71.7‡	31.7‡
	GSGA	10.51 ± 3.19	11.47 ± 3.03	9.55 ± 3.07	75.1 ± 22.8*‡	81.9 ± 21.7	68.2 ± 22.0*‡	45.0‡	61.7	28.3‡
	FMSA	11.63 ± 3.30	12.75 ± 3.22	10.50 ± 3.00	72.7 ± 20.6$^{\#}$	79.7 ± 20.1	65.7 ± 18.8$^{\#}$	31.7$^{*\#}$	50.0*	13.3$^{*\#}$

Table 2. Raw score, standardised score, and prevalence of advanced skills for each fundamental movement skill and assessment tool according to sex. TGMD: test of gross motor development. GSGA: get skilled get active. FMSA: fundamental motor skills assessment. *Significant difference ($p < 0.05$) with TGMD. #Significant difference ($p < 0.05$) with GSGA. ‡Significant difference ($p < 0.05$) with FMSA.

		Raw score (M ± SD)			Standardized score (M ± SD)			Advanced skills (%)		
		Grade 1–2	Grade 3–4	Grade 5–6	Grade 1–2	Grade 3–4	Grade 5–6	Grade 1–2	Grade 3–4	Grade 5–6
Run	TGMD	6.83 ± 1.57	7.47 ± 0.82	7.55 ± 0.88	85.3 ± 19.6$^{\#\ddagger}$	93.4 ± 10.2$^{\#\ddagger}$	94.4 ± 10.9$^{\#\ddagger}$	80.0$^{\#\ddagger}$	95.0$^{\#}$	92.5$^{\#}$
	GSGA	6.92 ± 2.63	8.05 ± 2.00	8.97 ± 2.60	57.7 ± 21.9*‡	67.1 ± 16.7*‡	74.8 ± 21.6*	17.5*‡	22.5*‡	55.0*‡
	FMSA	7.17 ± 1.69	8.18 ± 1.38	8.28 ± 1.40	71.7 ± 16.9$^{*\#}$	81.8 ± 13.8$^{*\#}$	82.8 ± 14.0*	55.0$^{*\#}$	70.0$^{\#}$	80.0$^{\#}$
Leap	TGMD	4.45 ± 1.08	4.35 ± 1.44	4.70 ± 1.16	74.2 ± 18.1$^{\#}$	72.5 ± 24.0$^{\#}$	78.3 ± 19.3$^{\#}$	70.0$^{\#\ddagger}$	67.5$^{\#\ddagger}$	77.5$^{\#\ddagger}$
	GSGA	6.92 ± 2.69	7.60 ± 2.67	8.13 ± 2.46	57.7 ± 22.4*‡	63.3 ± 22.2*‡	67.7 ± 20.5*‡	15.0*	22.5*	30.0*
	FMSA	7.00 ± 1.83	7.17 ± 2.00	7.88 ± 1.67	70.0 ± 18.3$^{\#}$	71.7 ± 20.0$^{\#}$	78.8 ± 16.7$^{\#}$	35.0*	40.0*	50.0*
Kick	TGMD	5.75 ± 1.78	6.15 ± 1.90	6.67 ± 1.38	71.9 ± 22.2‡	76.9 ± 23.8	83.4 ± 17.3$^{\#}$	42.5$^{\#\ddagger}$	60.0$^{\#\ddagger}$	62.5$^{\#\ddagger}$
	GSGA	8.40 ± 2.47	9.10 ± 2.50	9.32 ± 2.28	70.0 ± 20.6	75.8 ± 20.8	77.7 ± 19.0*	25.0*	45.0*	42.5*
	FMSA	9.28 ± 3.27	10.4 ± 3.35	11.1 ± 2.56	66.2 ± 23.3*	74.5 ± 23.9	79.1 ± 18.3	27.5*	42.5*	42.5*
Over-hand throw	TGMD	3.63 ± 1.58	4.80 ± 1.90	4.85 ± 2.21	45.3 ± 19.8$^{\#\ddagger}$	60.0 ± 23.7$^{\#\ddagger}$	60.6 ± 27.7$^{\#\ddagger}$	10.0	37.5	50.0
	GSGA	6.60 ± 2.30	8.15 ± 2.49	8.28 ± 2.94	55.0 ± 19.1*	67.9 ± 20.7*	69.0 ± 24.5*	10.0	35.0	47.5
	FMSA	6.67 ± 2.39	8.03 ± 2.34	7.95 ± 2.80	55.6 ± 19.9*	66.9 ± 19.5*	66.2 ± 23.3*	12.5	35.0	45.0
Catch	TGMD	3.58 ± 1.84	4.80 ± 1.32	5.35 ± 1.03	59.6 ± 30.6	80.0 ± 22.1$^{\#}$	89.2 ± 17.1	47.5$^{\#\ddagger}$	72.5‡	92.5‡
	GSGA	7.80 ± 2.84	10.2 ± 2.19	11.1 ± 1.38	65.0 ± 23.7	85.0 ± 18.2*	92.1 ± 11.5	25.0*	65.0	82.5
	FMSA	7.30 ± 3.08	9.82 ± 2.40	10.7 ± 1.65	60.8 ± 25.7	81.9 ± 20.0	89.4 ± 13.7	22.5*	55.0*	75.0*
Two-hand strike	TGMD	6.63 ± 2.64	7.08 ± 2.41	8.08 ± 2.24	66.2 ± 26.4$^{\#}$	70.8 ± 24.1	80.7 ± 22.3	37.5‡	50.0‡	67.5‡
	GSGA	9.85 ± 3.65	10.18 ± 2.95	11.50 ± 2.73	70.4 ± 26.1*‡	72.7 ± 21.1	82.2 ± 19.5	32.5‡	40.0	62.5
	FMSA	10.83 ± 3.59	11.13 ± 3.04	12.93 ± 2.90	67.7 ± 22.5$^{\#}$	69.6 ± 19.0	80.8 ± 18.1	17.5$^{*\#}$	25.0*	52.5*

Table 3. Raw score, standardised score, and prevalence of advanced skills for each fundamental movement skill and assessment tool according to school year. TGMD: test of gross motor development. GSGA: get skilled get active. FMSA: fundamental motor skills assessment. *Significant difference ($p < 0.05$) with TGMD. #Significant difference ($p < 0.05$) with GSGA. ‡Significant difference ($p < 0.05$) with FMSA.

compared to both the TGMD ($p < 0.001$) and GSGA ($p < 0.001$). Figure 1 presents a more detailed overview of the percentage of children demonstrating mastery, near-mastery, or poor mastery of each skill according to the assessment tool. In addition, the percentage of children demonstrating mastery of each skill component for each assessment tool by sex and school year is provided in Supplementary Tables S1–3.

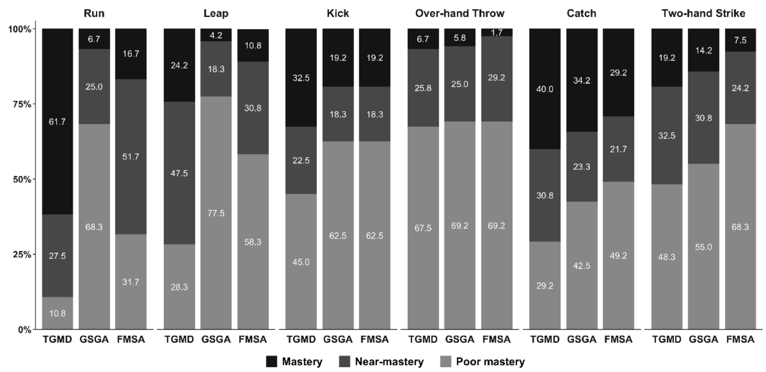

Fig. 1. Percentage of children showing mastery, near-mastery, or poor mastery of each fundamental movement skill according to the assessment tool.

Discussion

The present study aimed to examine the discrepancies between three different process-oriented instruments (TGMD, GSGA, and FMSA) used to assess the same FMS in primary school-aged children. To the best of the authors' knowledge, this is the first study to comprehensively analyse children's proficiency in FMS common to these assessment tools, while also considering factors such as sex and school year. The main findings indicate that, despite the large correlations between the assessment tools, significant differences were observed in the standardised scores obtained from each assessment tool across the six skills analysed. Furthermore, the TGMD consistently classified a higher percentage of children as possessing advanced skills in comparison to the GSGA and FMSA, particularly for the run, leap, kick and catch.

In a previous study, Logan et al.[15] also compared different process-oriented assessment tools, including the TGMD-2, GSGA, and Developmental Sequences, to evaluate the jump, hop, and over-hand throw. Consistent with the current findings, they[15] observed that a higher proportion of children were classified as having advanced skills when assessed using the TGMD. This suggest that achieving mastery or near-mastery in specific skill may be more attainable when using an assessment tool with fewer performance criteria, as opposed to one with a greater number of skill components[27]. Specifically, the TGMD comprises 3 to 4 execution criteria for the run, leap, kick, and catch, which is notably fewer than the 5–7 criteria used in the GSGA and FMSA. Therefore, while the TGMD may be effective for broadly screening children for developmental delays, more comprehensive tools like the GSGA or FMSA may provide a clearer differentiation between different proficiency levels[14,15]. Furthermore, this study adds to the existing body of knowledge by comparing the standardised scores derived from each assessment tool. The results showed that standardised scores were generally higher for either the TGMD or GSGA, depending on the skill. This variability can be attributed not only to the differences in the number of performance criteria but also to variations in the descriptions of these criteria for each skill in the different assessment tools[21].

The present findings highlight the limitations inherent in current process-oriented assessments of FMS, as noted in a recent review[21]. The growing variety of available assessment tools poses significant challenges for educators, practitioners, and researchers in selecting the most suitable instrument, while also complicating direct comparisons between children from different cultures, regions, or age groups, especially when different tools are used[10,13]. The situation is further compounded by the subjective nature of these assessments, which can introduce inconsistencies between research teams, even when the same instrument is used, thereby undermining the comparability of results[28]. For example, in the current study, a notable discrepancy was observed in the overarm throw compared to Logan et al.[15]. In their study, they reported significant differences between the TGMD and GSGA in identifying advanced throwing skills[15]. Such variations may arise from differences in the interpretation and scoring of these assessment tools by different research teams[28]. To address these inconsistencies, it seems crucial to standardise scoring procedures to enhance inter-rater reliability in FMS assessments[16]. As recently proposed for the TGMD-3, the development of more detailed and universally accepted scoring criteria is essential to ensure consistency across studies worldwide[29], particularly since the information provided in assessment manuals may be insufficient[28].

Among the FMS assessed in this research, the catch consistently yielded the highest standardized scores and prevalence of advanced skills in older children (Grades 5–6), aligning with findings from previous studies[7,18,30–32]. However, for other skills, there were notable discrepancies in the observed developmental trends between the different assessment tools. Therefore, an emphasis on mastery of each component of the FMS, rather than relying solely on raw scores or overall proficiency levels, may provide a more nuanced understanding of the differences between assessment tools[22]. This approach could also offer educators deeper insights into children's developmental status[33]. For instance, in the case of running, the GSGA uses more rigorous criteria (e.g., criteria 1, 3, or 5), making it more difficult to achieve advanced skills. In this context, as highlighted by previous scientific evidence on mastery of specific performance criteria[18,24,30,32,33], the most difficult criteria to master tended to be those requiring complex coordination, such as the coordinated use of upper and lower limbs or contralateral actions. Such criteria are generally more prevalent in the GSGA and FMSA assessments.

From a practical perspective, a primary aim of FMS assessments is to monitor developmental trends and patterns, enabling teachers and practitioners to identify motor delays in children and design appropriate interventions[12]. However, the present findings indicate that the choice of assessment tool plays a critical role in identifying children with poor mastery or motor delays. In this context, a tool that identifies more children with poor mastery may have higher sensitivity, meaning it is better at detecting motor delays. However, this increased sensitivity could come at the cost of reduced specificity, potentially leading to false positives and overdiagnosis. Such overdiagnosis may result in unnecessary interventions for children who are developing typically, thereby consuming resources and time. This raises concerns about the tool's ability to accurately distinguish between children with genuine delays and those whose motor skills fall within a normal range.

Limitations of the study

Regarding the limitations of the current study, some aspects should be acknowledged. Firstly, the relatively small sample size and the exclusive focus on children from a single geographical area may limit the generalisability of the findings. In this regard, previous research[21] has indicated that cultural and geographic factors significantly influence FMS proficiency, with skills such as the two-hand strike being context-specific to North America, which raises questions about their applicability in other regions. Secondly, although stability skills are a crucial component of motor development[34], they were not assessed in the present study, as the TGMD excludes these skills. Thirdly, from a methodological perspective, it is important to note that the GSGA and FMSA assessments were conducted in accordance with the TGMD procedures, rather than their own protocols. This may have potentially influenced the outcomes of these assessments[15]. Finally, the analysis of both process- and product-oriented measures could provide a more comprehensive understanding of the differences between FMS assessment tools.

Conclusions

The findings of the current study highlight the significant discrepancies between the outcomes of process-oriented FMS assessment tools in primary school-aged children. Notably, the TGMD tended to classify a higher percentage of children as having advanced skills compared to the GSGA and FMSA. This suggests that tools with fewer performance criteria for each skill may be less rigorous than more detailed assessments such as the GSGA and FMSA. The implications of using tools with differing identification rates underscore the need for educators, practitioners, and researchers to critically evaluate the strengths and limitations of each assessment method. Combining multiple tools or adopting a comprehensive, criterion-based approach may offer the most balanced understanding of children's motor development, ensuring accurate identification and appropriate support. Moreover, the study reinforces the importance of standardising scoring procedures and developing clearer, universally accepted criteria across FMS assessments.

Data availability

The datasets used and analysed during the current study are available from the corresponding author (zequirey@uvigo.es) on reasonable request.

Received: 25 October 2024; Accepted: 21 March 2025
Published online: 25 March 2025

References

1. Goodway, J. D., Gallahue, D. L. & Ozmun, J. C. *Understanding Motor Development: Infants, Children, Adolescents, Adults* 8th edn (Jones & Bartlett Learning, 2021).
2. Logan, S. W., Ross, S. M., Chee, K., Stodden, D. F. & Robinson, L. E. Fundamental motor skills: A systematic review of terminology. *J. Sports Sci.* **36** (7), 781–796 (2018).
3. Stodden, D. F. et al. Holistic functioning from a developmental perspective: A new synthesis with a focus on a multi-tiered system support structure. *Clin. Child. Fam Psychol. Rev.* **26** (2), 343–361 (2023).
4. Robinson, L. E. et al. Motor competence and its effect on positive developmental trajectories of health. *Sports Med.* **45** (9), 1273–1284 (2015).
5. Barnett, L. M. et al. Through the looking glass: A systematic review of longitudinal evidence, providing new insight for motor competence and health. *Sports Med.* **52** (4), 875–920 (2022).
6. Cattuzzo, M. T. et al. Motor competence and health related physical fitness in youth: A systematic review. *J. Sci. Med. Sport*. **19** (2), 123–129 (2016).
7. Behan, S., Belton, S., Peers, C., O'Connor, N. E. & Issartel, J. Moving well-being well: Investigating the maturation of fundamental movement skill proficiency across sex in Irish children aged five to twelve. *J. Sports Sci.* **37** (22), 2604–2612 (2019).
8. Bolger, L. E. et al. Global levels of fundamental motor skills in children: A systematic review. *J. Sports Sci.* **39** (7), 717–753 (2021).
9. Zheng, Y., Ye, W., Korivi, M., Liu, Y. & Hong, F. Gender differences in fundamental motor skills proficiency in children aged 3–6 years: A systematic review and meta-analysis. *Int. J. Environ. Res. Public. Health*. **19** (14), 8318 (2022).
10. Eddy, L. H. et al. The validity and reliability of observational assessment tools available to measure fundamental movement skills in school-age children: A systematic review. *PLoS One* **15**(8), e0237919 (2020).
11. Scheuer, C., Herrmann, C. & Bund, A. Motor tests for primary school aged children: A systematic review. *J. Sports Sci.* **37** (10), 1097–1112 (2019).
12. Bardid, F., Vannozzi, G., Logan, S. W., Hardy, L. L. & Barnett, L. M. A Hitchhiker's guide to assessing young People's motor competence: Deciding what method to use. *J. Sci. Med. Sport*. **22** (3), 311–318 (2019).
13. Hulteen, R. M. et al. Validity and reliability evidence for motor competence assessments in children and adolescents: A systematic review. *J. Sports Sci.* **38** (15), 1717–1798 (2020).
14. Hulteen, R. M., True, L. & Pfeiffer, K. A. Differences in associations of product- and process-oriented motor competence assessments with physical activity in children. *J. Sports Sci.* **38** (4), 375–382 (2020).
15. Logan, S. W., Barnett, L. M., Goodway, J. D. & Stodden, D. F. Comparison of performance on process- and product-oriented assessments of fundamental motor skills across childhood. *J. Sports Sci.* **35** (7), 634–641 (2017).

16. Rey, E., Carballo-Fazanes, A., Varela-Casal, C. & Abelairas-Gómez, C. ALFA-MOV project collaborators. Reliability of the test of gross motor development: A systematic review. *PLoS One*. **15** (7), e0236070 (2020).
17. Ulrich, D. A. *Test of Gross Motor Development* 2nd edn (Pro-Ed, 2000).
18. Ulrich, D. A. *Test of Gross Motor Development* 3rd edn (Pro-Ed, 2019).
19. NSW Department of Education and Training. *Get Skilled: Get Active. A K-6 Resource To Support the Teaching of Fundamental Movement Skills* (NSW Department of Education and Training, 2000).
20. Department of Education Victoria. *Fundamental Motor Skills: A Manual for Classroom Teachers* (Department of Education, 1996).
21. Hulteen, R. M. et al. Reinvest to assess: Advancing approaches to motor competence measurement across the lifespan. *Sports Med.* **53** (1), 33–50 (2023).
22. Foulkes, J. D. et al. Fundamental movement skills of preschool children in Northwest England. *Percept. Mot Skills*. **121** (1), 260–283 (2015).
23. Faul, F., Erdfelder, E., Lang, A. G. & Buchner, A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods*. **39** (2), 175–191 (2007).
24. Booth, M. L. et al. Mastery of fundamental motor skills among new South Wales school students: Prevalence and sociodemographic distribution. *J. Sci. Med. Sport*. **2** (2), 93–105 (1999).
25. Bolger, L. E. et al. Age and sex differences in fundamental movement skills among a cohort of Irish school children. *J. Motor Learn. Dev.* **6** (1), 81–100 (2018).
26. Hopkins, W. G., Marshall, S. W., Batterham, A. M. & Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med. Sci. Sports Exerc.* **41** (1), 3–13 (2009).
27. Okely, A. D. & Booth, M. L. Mastery of fundamental movement skills among children in new South Wales: Prevalence and sociodemographic distribution. *J. Sci. Med. Sport*. **7** (3), 358–372 (2004).
28. Hulteen, R. M., True, L. & Kroc, E. Trust the process? When fundamental motor skill scores are reliably unreliable. *Meas. Phys. Educ. Exerc. Sci.* **27** (4), 391–402 (2023).
29. Carballo-Fazanes, A., Rey, E., Valentini, N. C., Varela-Casal, C. & Abelairas-Gómez, C. Interrater reliability of the test of gross motor Development—Third edition following raters' agreement on measurement criteria. *J. Motor Learn. Dev.* **11** (2), 225–244 (2023).
30. Hardy, L. L., Mihrshahi, S., Drayton, B. A. & Bauman, A. *NSW Schools Physical Activity and Nutrition Survey (SPANS) 2015: Full Report* (NSW Department of Health, 2016).
31. Valentini, N. C. et al. Fundamental motor skills across childhood: Age, sex, and competence outcomes of Brazilian children. *J. Motor Learn. Dev.* **4** (1), 16–36 (2016).
32. Lawson, C., Eyre, E. L. J., Tallis, J. & Duncan, M. J. Fundamental movement skill proficiency among British primary school children: Analysis at a behavioral component level. *Percept. Mot Skills*. **128** (2), 625–648 (2021).
33. Hardy, L. L., King, L., Farrell, L., Macniven, R. & Howlett, S. Fundamental movement skills among Australian preschool children. *J. Sci. Med. Sport*. **13** (5), 503–508 (2010).
34. Rudd, J. R. et al. Fundamental movement skills are more than run, throw and catch: The role of stability skills. *PLoS One* **10**(10), e0140224 (2015).

Acknowledgements

This work was supported by MCIN/AEI/10.13039/501100011033/ and European Regional Development Fund (ERDF), a way to make Europe, under grant PID2021-128640OB-I00. Miguel Lorenzo-Martínez was supported by the Spanish Ministry of Universities under application 33.50.460 A.752 and European Union NextGenerationEU/PRTR under grant Margarita Salas from the University of Vigo.

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Conceptualization: E.R., C.A-G.; Methodology: M.L-M., E.R., C.A-G.; Formal analysis: M.L-M.; Writing - original draft preparation: M.L-M.; Writing - review and editing: M.L-M., E.R., C.A-G.; Funding acquisition, project administration and supervision: E.R., C.A-G. All authors have read and agreed to the published version of the manuscript.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-025-95500-1.

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