



Original research

Normative percentile values for the TGMD-3 for Italian children aged 3–11 + years

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ABSTRACT

Objectives: Sufficient gross motor skill proficiency is an essential prerequisite for the successful performance of sport-specific skills and physical activities. The Test of Gross Motor Development is the most common tool for assessing motor skills in paediatric populations, however, there is a lack of 'normative' data available against which children's scores can be compared. Normative data would enable the comparison of an individual's motor development to age-standardised norms. The aim of this study was to develop normative data for the Test of Gross Motor Development Third Edition scores for Italian children.

Design: The Test of Gross Motor Development Third Edition scores from > 17,000 Italian children (aged 3–11 + years) were analysed to develop normative scores and percentiles.

Methods: Total Test of Gross Motor Development Third Edition scores and locomotor and ball skills subscale scores were split by age and sex. Using the LMS method, based on the Box-Cox transformation, percentiles were calculated for each sex-specific age category.

Results: 17,026 children were included in the analysis ($n = 8262$ girls; $n = 8766$ boys).

Conclusions: This is the largest sample ever used to develop normative data for the Test of Gross Motor Development and the first set of normative data for European children. This normative data can be used to identify insufficient motor skill development and aid subsequent modification of activities to nurture sufficient motor skill proficiency. This is particularly important for children in the lower percentiles given the strong associations between early childhood fundamental motor skill competence and physical activity participation in adolescence and adulthood.

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Practical implications

- The development of this normative data for gross motor skills (by age and sex) enables comparison of a child's data with normative/expected values, and subsequently the identification of children who lack proficiency in motor skill development relative to their age and sex norms.
- Identification of children with motor skill incompetency allows for timely and appropriate interventions to increase motor skill proficiency.

- This set of normative data can be used by a vast array of practitioners to modify and adapt the activities they deliver in lessons/training sessions to nurture sufficient development of and proficiency in motor skills.
- Early interventions to prevent motor skill incompetency and encourage mastery of gross motor skills may ultimately foster the likelihood of life-long physical activity.

1. Introduction

Gross motor skills are described as goal-directed movement patterns that involve large whole-body movements, locomotion, and full body stretches.¹ Sufficient proficiency in gross motor skills is an essential prerequisite for the successful performance of sport-specific skills, and for

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participation in an array of physical activities.^{2,3} Inadequate proficiency in gross motor skills has frequently demonstrated associations with reduced perceived physical competence,⁴ lessened self-esteem, and lower levels of social acceptance in childhood.^{5,6} As a consequence of this, poor gross motor skill competency is suggested to also negatively affect competencies and proficiency in physical and motor activities later in life.^{7,8} Therefore, it is unsurprising that gross motor skill competency and sufficient development of motor skills have been identified as a predictor of improved levels of health-related physical fitness, physical activity

behaviour, and better health outcomes across the lifespan.^{8–10} Longitudinal and cross-sectional research has also revealed that motor skill competency is associated with sustained levels of physical activity and health-related fitness over time.¹¹

Motor skill competency has also been positively associated with enjoyment of, and perceived competence for, physical activity.¹² Considering the huge importance of proficient motor skill development in childhood,¹³ having a valid and reliable method of assessing gross motor skill development in children is crucial. Assessing the proficiency

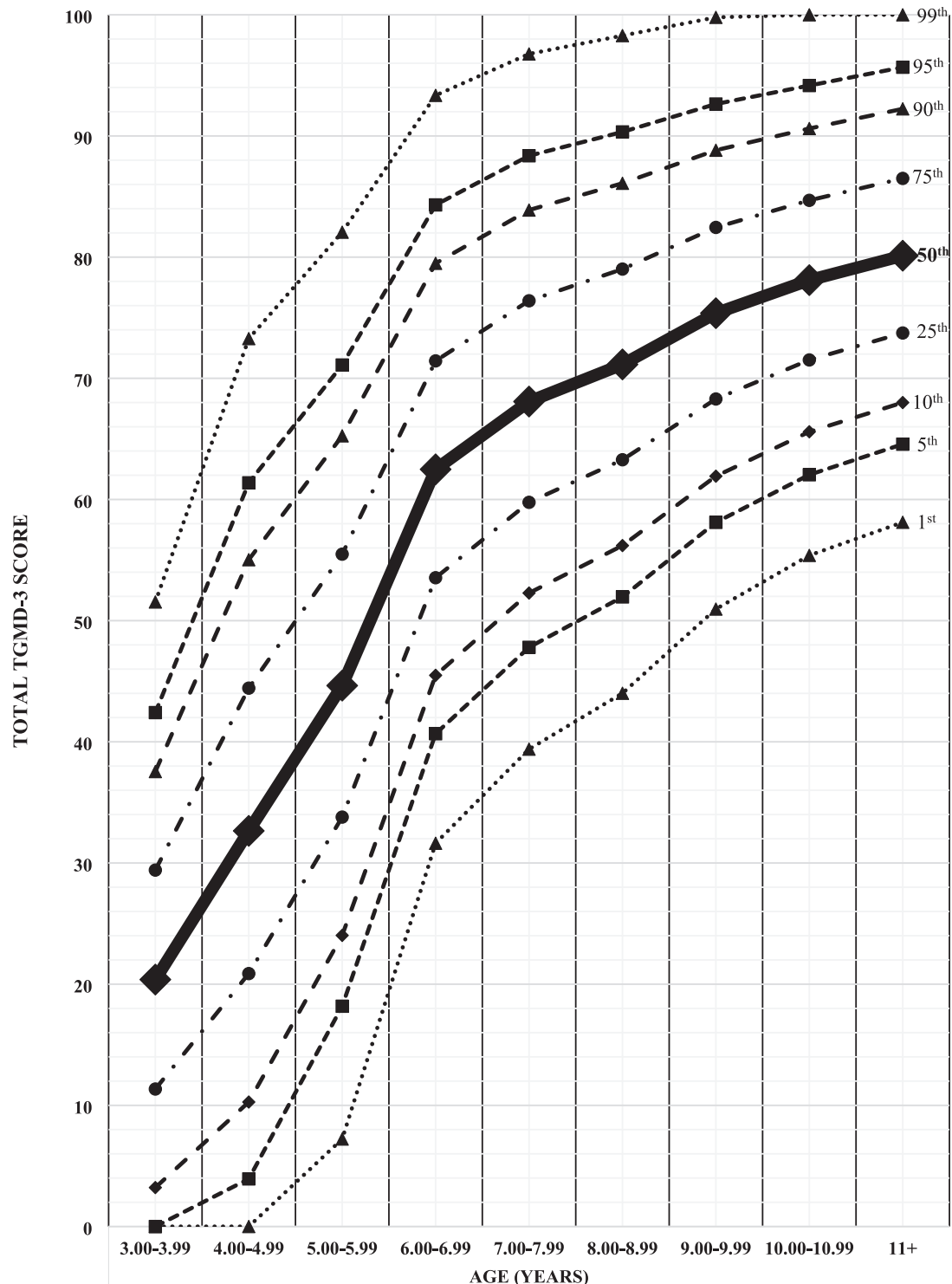


Fig. 1. TGMD-3 total score percentiles for girls aged 3–11+ years.

and development of gross motor skills in children provides valuable information which can aid the identification of possible motor skill developmental delays and deficits. However, for the information acquired from these assessments to be valuable and insightful, the assessment tool used must be both reliable and valid. Furthermore, the availability of normative data for comparison of a child's development relative to others is incredibly insightful and useful for the interpretation of data from the tests used to assess gross motor performance.

The Tests of Gross Motor Development (TGMD)¹⁴ is the most commonly used measurement tool for assessing gross motor skill proficiency in paediatric research. The latest version of the TGMD is the TGMD-3 (3rd Edition), which is a process-orientated test of gross motor skills designed for children aged 3–11 years. The TGMD-3 is a criterion-based test which includes a comprehensive battery of skills and is divided into two subsets: locomotor skills, which includes skills such as running, jumping, hopping, galloping, sliding, and skipping; and ball skills, which includes skills such as throwing, catching, dribbling, kicking, and striking a ball. The TGMD-3 is scored according to the presence or absence of the set criterion for each skill. The TGMD-3

can be used to identify developmental delays in gross motor performance, evaluate intervention programmes designed to improve gross motor skills, and assess changes that develop with age, experience, instruction, or intervention.¹⁴ The TGMD-3 has demonstrated good validity and reliability for assessing gross motor skills in children.^{15,16} Webster and Ulrich¹⁶ demonstrated that test-retest reliability had high intraclass correlation coefficient agreements for the locomotor skills (0.97), ball skills (0.95), and total TGMD-3 score (0.97), whilst Magistro et al.¹⁵ showed strong inter-rater reliability for TGMD-3 total scores (0.996) and for both sub-scales (locomotor skills: 0.996; ball skills: 0.997).

Although the TGMD-3 has been demonstrated to be a reliable and valid tool to assess gross motor skills, there is a lack of 'normative' data available against which children's scores can be compared. Such normative data would be useful for comparing an individual child's performance in the TGMD-3 to those of age-standardised norms; and assessing whether a child is developing motor skills typical for their age. Therefore, the present study reports TGMD-3 performance in a cohort of over 17,000 Italian children (aged 3–11 + years) to develop normative values (in the form of percentiles) for locomotor skills and ball

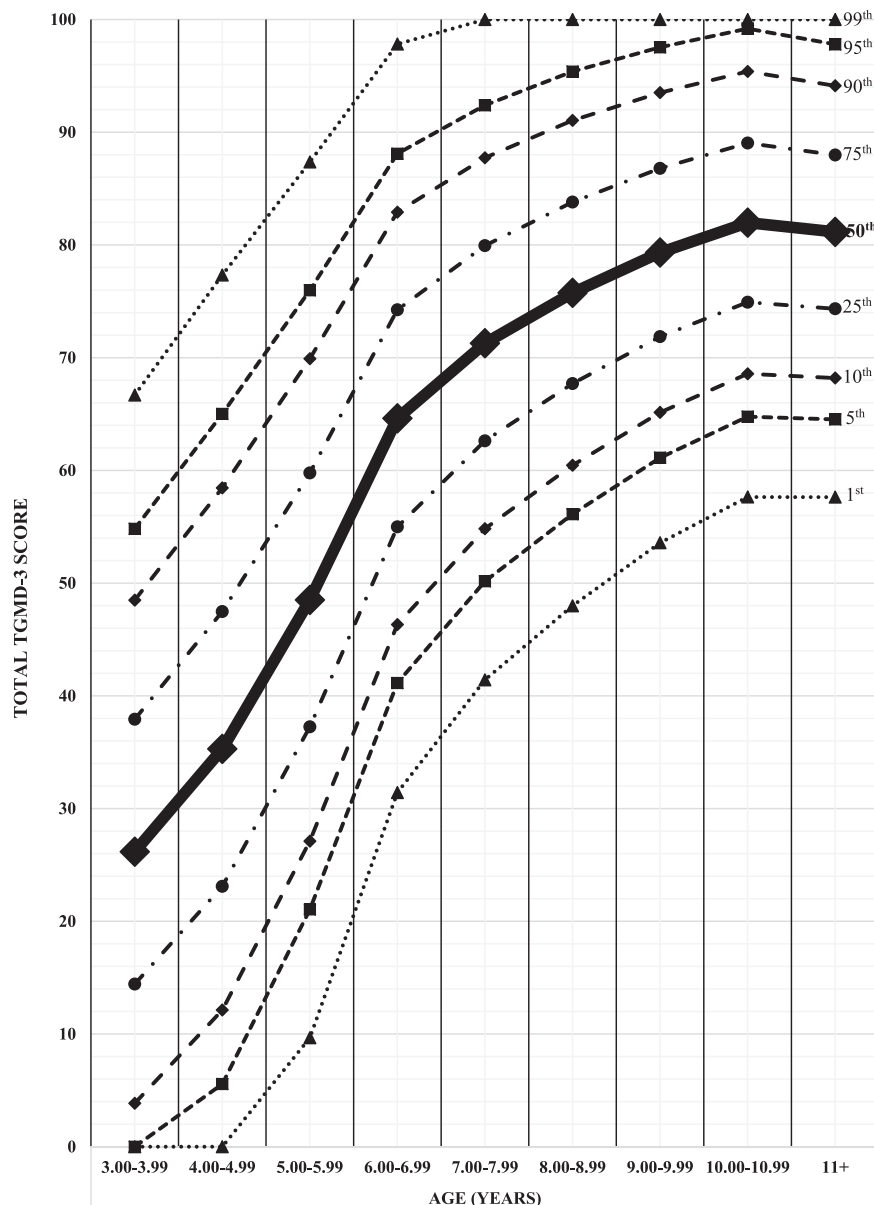


Fig. 2. TGMD-3 total score percentiles for boys aged 3–11+ years.

skills subscales and the total score for the TGMD-3. Using this very large cohort of European children, this study aimed to produce normative values for the TGMD-3 to assess gross motor skills which can be applied to European children. This is essential given the current lack of any normative data for European children and the size of the cohort used to develop these normative values.

2. Methods

The study involved 67 primary schools located in the north-west area of Italy. A total of 17,028 (51 % boys) children aged 3–11+ years completed the TGMD-3. For context, the population of children in pre-school and primary school in Northern Italy at the start of data collection (March 2020) was 928,938.¹⁷ To ensure a representative sample for our study,¹⁸ we calculated the required sample size using the formula for simple random sampling. For a population size (N) of 928,938, with a 95 % confidence interval (CI) and a margin of error (E) of ± 1 %, the adjusted minimum sample size was estimated to be 9506 participants. The TGMD-3 tests were conducted in each school's gymnasium by a team of 16 professionals, comprising 4 sport science researchers, 2

psychologists, and 10 physical education professionals. Prior to administering the tests, all examiners participated in a comprehensive 2-hour session to familiarise themselves with the test protocol. The tests were administered during regular school hours. Written informed consent was obtained from the parents/guardians of each child and verbal assent was obtained from each child. The ethical committee of the University of Torino approved the study (study ID 100949).

2.1. The TGMD-3

The TGMD-3 was divided into two sub-scales: locomotor skills and ball skills.¹⁵ The locomotor skills sub-scale was made up of six skills: run, gallop, hop, horizontal jump, slide (each judged on four performance criteria) and skip (judged on three performance criteria). The ball skills sub-scale was comprised of seven skills: one handed forehand strike of a tennis ball, kick of a football, overarm throw, underarm throw of a small ball (each judged on four criteria), two-hand strike of a stationary ball (judged on five criteria), one hand stationary dribble of a basketball, and a two-handed catch of a small ball (each judged on three criteria). For each skill the examiner provided a verbal description

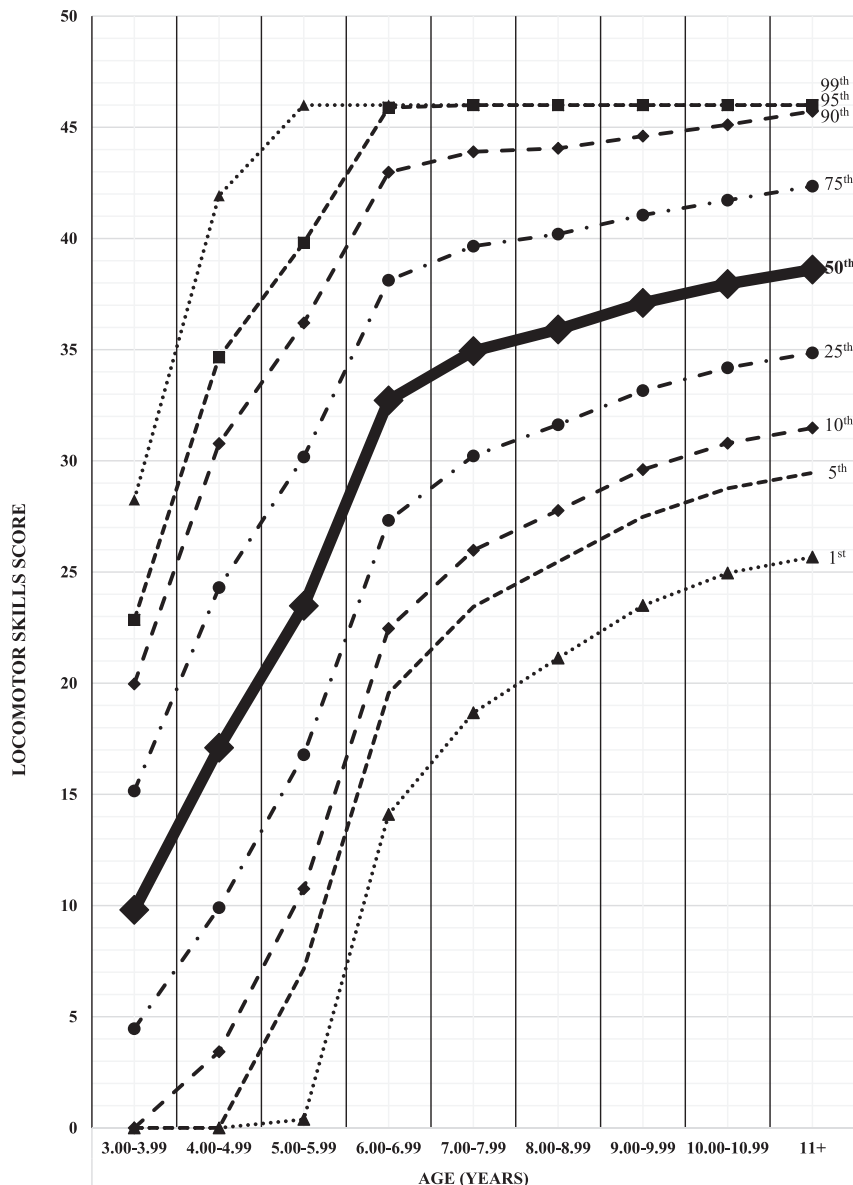


Fig. 3. TGMD-3 total locomotor skills score percentiles for girls aged 3–11+ years.

and visual demonstration of each skill prior to the completion of the TGMD-3. Each participant had one practice of each skill followed by two recorded attempts of each skill. Performances were observed and evaluated using the qualitative performance criteria for each TGMD-3 assessment skill, with each performance criterion scored as achieved (score awarded = 1) or not (score awarded = 0). The total score for each item was calculated by the sum of both trials for each TGMD-3 skill. The locomotor skills subscale score was out of 46, the ball skills subscale score was out of 54, and the total TGMD-3 score was out of 100. The total score was calculated as locomotor skills + ball skills. The total TGMD-3 score, alongside scores for the locomotor skills and ball skills subscales, was then used to create age- and sex-specific percentiles.

2.2. Data analysis

Participants were placed into one-year age categories (e.g. 3.00–3.99 up to 11.00–11.99 years). Participants in each age category were then split according to sex. Percentiles were constructed using the LMS method based on the Box–Cox transformation.¹⁹ This approach utilises three parameters: Lambda (L), Median (M), and the coefficient of variation (S),

which are smoothed across time points t (in years). The smoothness of the $L(t)$, $M(t)$, and $S(t)$ curves can be adjusted by calibrating their degrees of freedom to achieve an optimal balance between data fit and model smoothness.²⁰ The degrees of freedom were estimated to determine the optimal model using the Generalised Akaike Information Criterion (GAIC). The fit of the optimal model was evaluated through visual inspection of quantile residuals, density estimates, and Q–Q plots. Separate models were developed for boys and girls in relation to locomotor skills, ball skills, and the total score of the TGMD-3. From these models, percentiles (1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 99th) were estimated. All analyses were performed using the *GAMLSS*²¹ package in R.

3. Results

A total of 17,028 children were included in the analysis ($n = 8259$ girls; $n = 8767$ boys [Supplementary Table 1]). Percentiles for the total TGMD-3 score for girls (Table 1, Fig. 1) and boys (Table 1, Fig. 2) are presented. Percentiles are also presented for the locomotor skills subscale (girls [Table 2, Fig. 3]; boys [Table 2, Fig. 4]) and ball skills subscale (girls [Table 3, Fig. 5]; boys [Table 3, Fig. 6]).

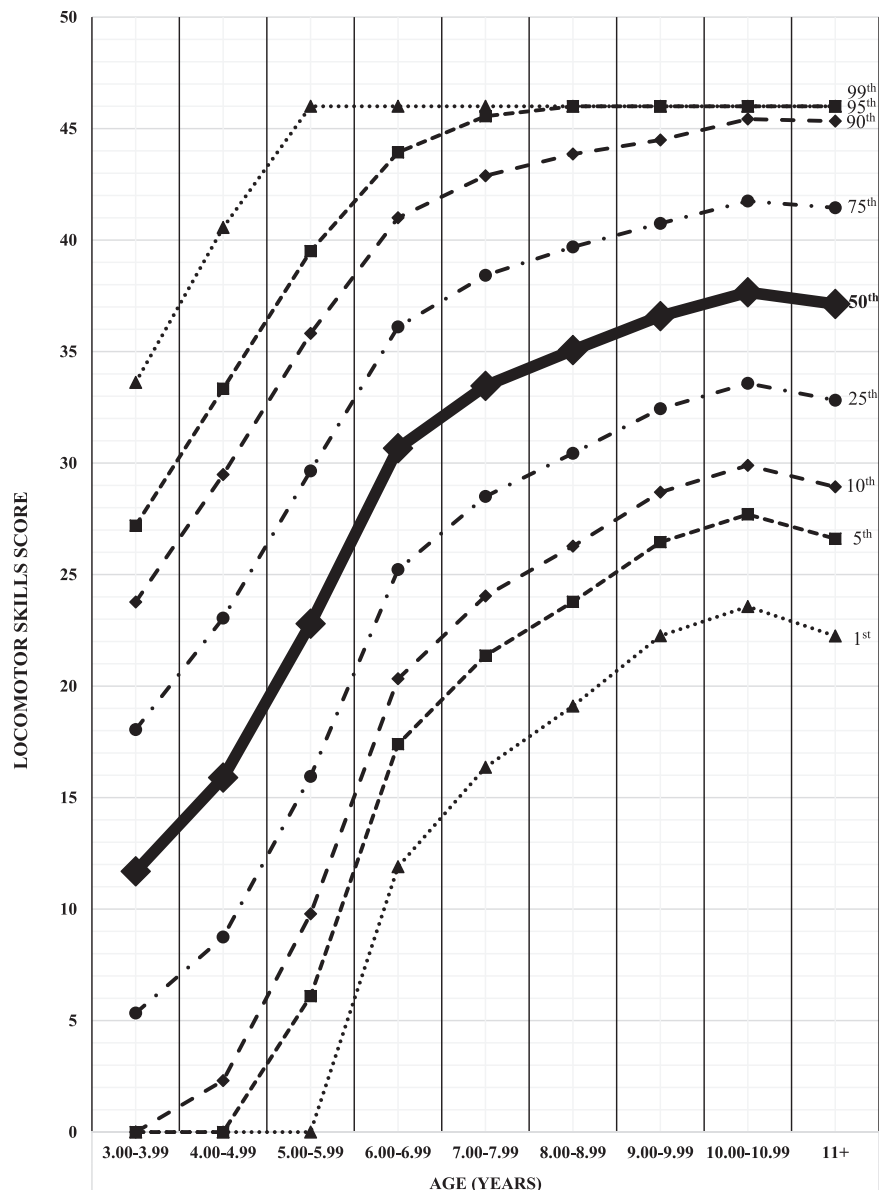


Fig. 4. TGMD-3 total locomotor skills score percentiles for boys aged 3–11+ years.

4. Discussion

This is the first time that age- and sex-specific normative data have been produced for the assessment of motor skill development for a European based cohort of children using TGMD-3 scores. These normative scores and percentiles have been produced using TGMD-3 score data from over 17,000 Italian children (girls and boys). This is the largest sample ever used for normative data for the TGMD-3, much larger than the data used to produce the normalised scores during the development of the TGMD-2 ($n = 1208$)²² and the data produced using the TGMD-2 from USA children ($n = 352$),²³ and, importantly, is also the first-time that normative data have been produced for a European-based cohort of children. This is of great importance given the vast socio-environmental differences between the USA and Europe. Consequently, European specific normative data is essential to allow for accurate assessment of motor skill competency for children at different ages. Additionally, this very large number in this analysis gives a more representative sample.

The production of these normative data is an imperative development because it enables teachers, coaches, and practitioners to identify

an individual child's competence in different motor skills. Consequently, this allows the modification and adaptation of physical education lessons and physical activity sessions depending on which motor skills a child lacks competence in. Identifying any delays in the development of motor skills in children is essential to allow for timely and appropriate interventions to subsequently mitigate the negative impact on the development of subsequent skills.²⁴ Early identification and intervention are vital because early childhood has been described as a pivotal period where children build foundational movement capacities which enable the progression to more complex and context-specific physical activities in later childhood, adolescence, and adulthood.²⁵ Optimal fundamental motor skill development in early childhood is the basis of adult health and wellbeing.²⁶ These fundamental motor skills that develop in early childhood have been described as the initial building blocks of more complex, coordinated movements²⁷ and, consequently, it has been suggested that fundamental motor skills and physical activity have a reciprocal and dynamic relationship whereby at a young age, engagement in physical activity may drive fundamental motor skill development which, in turn, drives further engagement in physical activity at a later age.⁸ Sport participation may serve to concomitantly

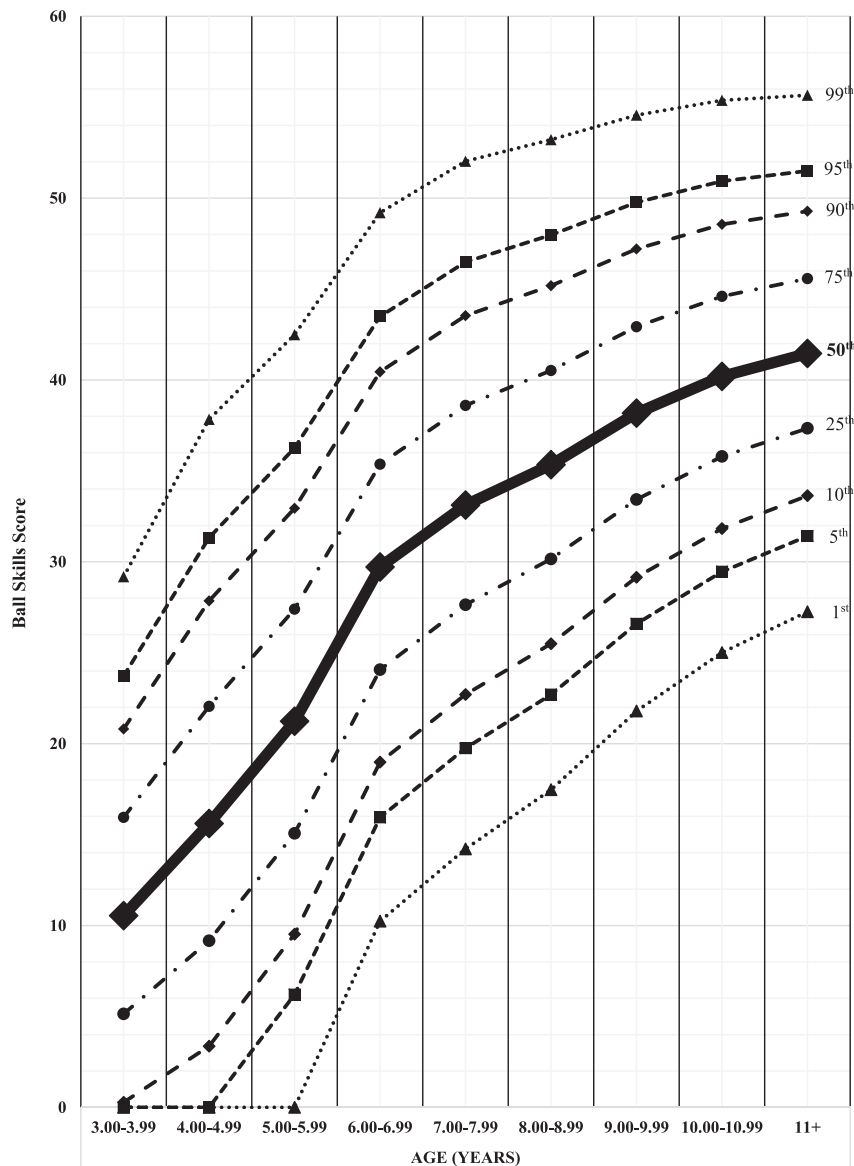


Fig. 5. TGMD-3 total ball skills score percentiles for girls aged 3–11+ years.

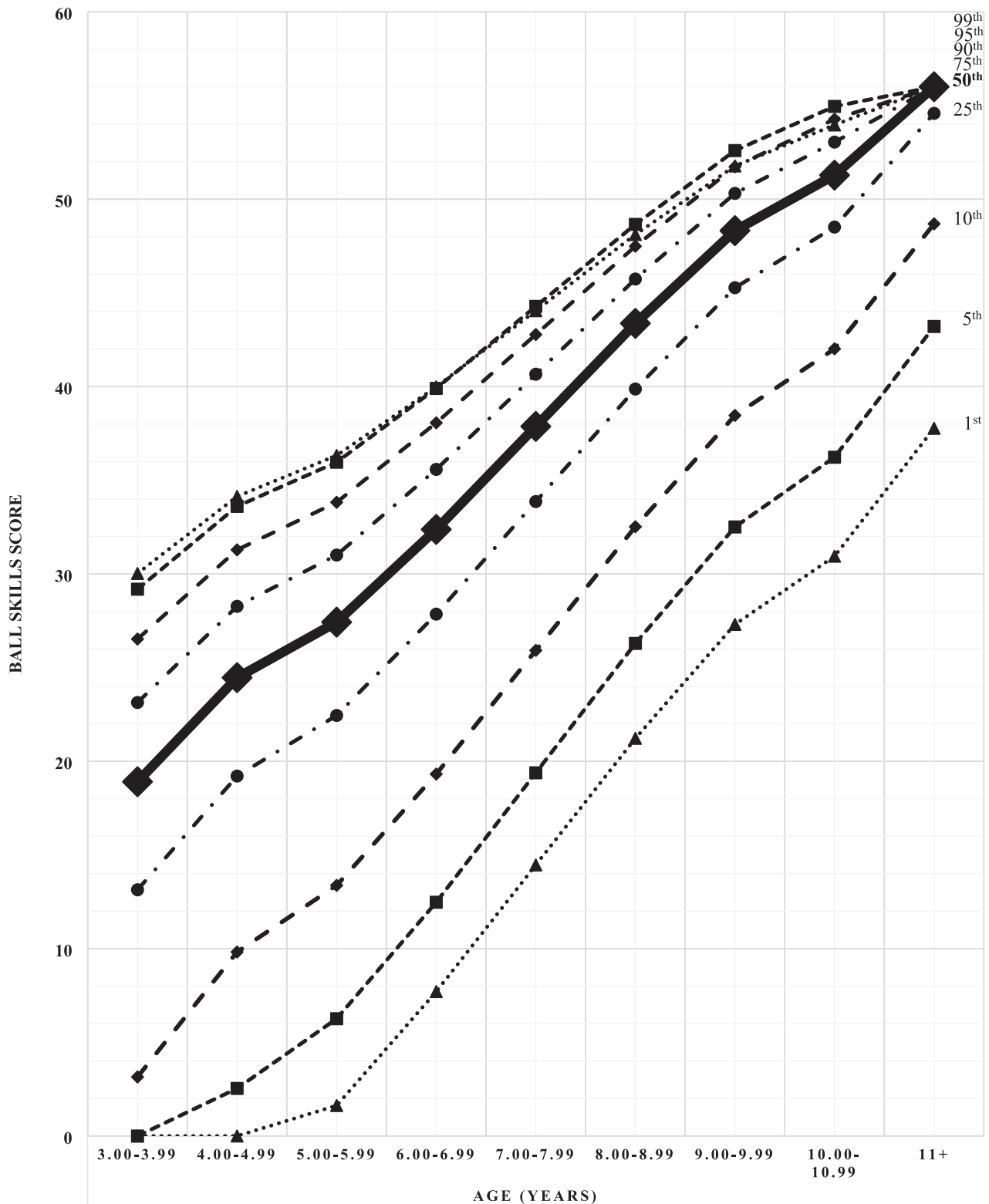


Fig. 6. TGMD-3 total ball skills score percentiles for boys aged 3–11+ years.

enhance motor skill competence and multiple aspects of health-related physical fitness.²⁸

The development of age and sex-specific normative percentiles to assess gross motor skill development for this very large cohort of European children is critical to enable the identification of children who are below the normative level of development for their age to enable timely and effective interventions to promote motor skill

competency. Strong evidence exists for an inverse association between motor skill competency and body weight, alongside positive associations between motor skill competency and cardiorespiratory and musculoskeletal fitness in children and adolescents.^{29,30} This association is suggested to be a consequence of higher engagement in physical activity by young people with better motor skill development (likely due to greater [perceived] competence), which resultantly promote better

Table 1
TGMD-3 Total Score Percentiles for Children Aged 3–11 + Years.

Percentile	Gender	Age (years)								
		3.00–3.99	4.00–4.99	5.00–5.99	6.00–6.99	7.00–7.99	8.00–8.99	9.00–9.99	10.00–10.99	11 +
1st	Boys	0	0	10	31	41	48	54	58	58
	Girls	0	0	7	32	39	44	51	55	58
5th	Boys	0	6	21	41	50	56	61	65	65
	Girls	0	4	18	41	48	52	58	62	65
10th	Boys	4	12	27	46	55	60	65	69	68
	Girls	3	10	24	45	52	56	62	66	68
25th	Boys	14	23	37	55	63	68	72	75	74
	Girls	11	21	34	54	60	63	68	72	74
50th	Boys	26	35	49	65	71	76	79	82	81
	Girls	20	33	45	62	68	71	75	78	80
75th	Boys	38	47	60	74	80	84	87	89	88
	Girls	29	44	55	71	76	79	82	85	86
90th	Boys	48	58	70	83	88	91	94	95	94
	Girls	38	55	65	79	84	86	89	91	92
95th	Boys	55	65	76	88	92	95	98	99	98
	Girls	42	61	71	84	88	90	93	94	96
99th	Boys	67	77	87	98	100	100	100	100	100
	Girls	52	73	82	93	97	98	100	100	100

levels of health-related physical fitness.²⁹ Lack of fundamental motor skill competence (the prerequisites of successful performance of sports and physical activities) reduces engagement in physical activity & sport in later childhood and throughout the lifespan.^{31,32} Therefore, timely and effective identification and subsequent intervention to promote motor skill competency are likely to have a beneficial impact on health-related physical fitness.

One key observation of this analysis is that gross motor skills (both ball skills and locomotor skills) improve with age. This observation is expected in line with normal childhood development and is also consistent with previous literature reporting improved fundamental motor skills with age.^{33–35} Indeed, the findings of the present study demonstrate that the most rapid acceleration in motor skill development appears to be between the ages of 3 and 7 years, in line with previous suggestions that the ‘golden age’ for motor development is between the ages of three and six years.³⁶ The first six years of childhood is devoted to learning and practising fundamental motor skills in an exploratory and experimental manner, including locomotor skills, object-control skills (ball skills), and posture-control skills.³⁷ A previous study of 1046 children found that the average annual improvements in locomotor and object-control (ball) skills were highest among children aged 4–5 and 3–6 years, respectively.³⁸ In addition to this, there is reportedly a plateauing in the increase in motor skill performance between the ages 8 and 10,³⁴ which is also in line with the findings of

the present study. The age-related improvement in fundamental motor skills (in ages 3–7 years), as demonstrated in the present study, has been suggested to likely result from a combination of maturation, increased instruction from teachers/coaches/practitioners (alongside improved comprehension and ability to follow instructions with age), increased quantity and quality of feedback, and more opportunities and desire to practice these motor skills (linked to an increase in understanding of their importance as a prerequisite for more complex skills) as age increases.^{39,40}

The concept of different motor skills developing at different times is demonstrated in the present analysis. The normative percentiles developed in the current study show that locomotor skills appear to develop at an earlier age than ball skills. This is consistent with previous research suggesting that children’s basic motor development follows the principle of improving from simple movement to complex movement and from low-level skill to high-level skill.³⁶ It has been reported that at each respective age (and age range), children exhibit higher levels of locomotor skills compared to object control skills.⁴¹ In this aforementioned study, when children were classified according to TGMD-2 performance categories, no child exhibited “very superior” levels of object control skills and specifically the throw and roll skills (both object control skills) were found to be among the least proficient skills across all age groups and ranges. This supports the suggestion that due to the greater perceptual demand and complexity of object control skill

Table 2
TGMD-3 locomotor skills score percentiles for children aged 3–11 + years.

Percentile	Gender	Age (years)								
		3.00–3.99	4.00–4.99	5.00–5.99	6.00–6.99	7.00–7.99	8.00–8.99	9.00–9.99	10.00–10.99	11 +
1st	Boys	0	0	0	12	16	19	22	24	22
	Girls	0	0	0	14	19	21	23	25	26
5th	Boys	0	0	6	17	21	24	26	28	27
	Girls	0	0	7	20	23	25	27	29	29
10th	Boys	0	2	10	20	24	26	29	30	29
	Girls	0	3	11	22	26	28	30	31	31
25th	Boys	5	9	16	25	29	30	32	34	33
	Girls	4	10	17	27	30	32	33	34	35
50th	Boys	12	16	23	31	33	35	37	38	37
	Girls	10	17	23	33	35	36	37	38	39
75th	Boys	18	23	30	36	38	40	41	42	41
	Girls	15	24	30	38	40	40	41	42	42
90th	Boys	24	29	36	41	43	44	44	45	45
	Girls	20	31	36	43	44	44	45	45	46
95th	Boys	27	33	40	44	46	46	46	46	46
	Girls	23	35	40	46	46	46	46	46	46
99th	Boys	34	41	46	46	46	46	46	46	46
	Girls	28	42	46	46	46	46	46	46	46

Table 3
TGMD-3 ball skills score percentiles for children aged 3–11+ years.

Percentile	Gender	Age (years)								
		3.00–3.99	4.00–4.99	5.00–5.99	6.00–6.99	7.00–7.99	8.00–8.99	9.00–9.99	10.00–10.99	11 +
1st	Boys	0	0	3	13	19	23	27	29	30
	Girls	0	0	0	10	14	17	22	25	27
5th	Boys	0	3	10	19	24	28	31	34	34
	Girls	0	0	6	16	20	23	27	29	31
10th	Boys	0	6	13	22	27	31	34	36	36
	Girls	0	3	10	19	23	25	29	32	34
25th	Boys	8	12	19	28	32	36	38	40	40
	Girls	5	9	15	24	28	30	33	36	37
50th	Boys	14	19	26	34	38	41	43	44	44
	Girls	11	16	21	30	33	35	38	40	41
75th	Boys	21	26	33	40	43	46	47	49	48
	Girls	16	22	27	35	39	41	43	45	46
90th	Boys	27	33	38	45	48	50	52	53	52
	Girls	21	28	33	40	44	45	47	49	49
95th	Boys	31	36	42	49	51	53	54	55	54
	Girls	24	31	36	43	46	48	50	51	51
99th	Boys	38	43	49	55	56	56	56	56	56
	Girls	29	38	42	49	52	53	55	55	56

components these skills require greater instruction and practice compared to locomotor skills. It has been suggested that more complicated object control skills therefore may develop slower than the (simpler) locomotor skills initially, in the early stages of development,³⁶ but as the nervous system matures, the development of object-control skills accelerates and may even exceed that of the locomotor skills. These findings are supported by our data.

Visual interpretation of the sex-specific percentiles developed suggests a similar pattern of improvement in motor skill development for both boys and girls. Sex differences in the present study were not assessed statistically as this was not the aim of this investigation. However, in studies where sex differences have been analysed, there are conflicting findings. Similar to the visual interpretation of the present study, some studies report no sex differences in locomotor skill acquisition.^{33,42} It has been suggested that this is, at least in part, due to the fact that children of both sexes grow at approximately the same rate until the adolescent growth spurt⁴³; therefore, physical differences are unlikely responsible for any differences in motor skill development subsets (locomotor and ball skills). In contrast, other sex-related studies report better fundamental motor skill proficiency among boys.^{34,44} Boys have also demonstrated superior object control (ball) skills whilst girls have been reported to have more proficient locomotor skills (at the same age).^{13,45} Hardy et al.⁴⁵ and Barnett et al.¹³ both reported more proficient locomotor skills in girls and higher object control scores in boys among Australian children. Wang et al.³⁶ recently added to this body of literature by reporting that girls often out-perform boys in locomotor skill development in early childhood (up to 5-years of age), which was similar to the results of Kit et al.²³ Nonetheless, the findings of the present study suggest that in a very large cohort the developmental trajectories of gross motor skills (visually) appear to be similar between boys and girls aged 3–11+ years.

Various social-cultural factors are also suggested to have a substantial impact on motor skill development.⁴⁶ Biased engagement in certain sports, preferring certain physical activities, and certain sex-specific roles, expectations, and assumptions are some of the socio-cultural factors suggested to influence motor skill development.³⁴ Socio-cultural factors differ significantly between different cultures, which offers an explanation regarding the inconsistent literature on this topic. This is therefore why this present study of > 17,000 Italian children is so crucial, to ensure that children's data is being compared to culturally similar normative values.

One of the key strengths of the present study was the large sample, ensuring a representative sample of the population, which is particularly important in studies such as this that provide normative data against which comparisons can be made. However, the present study

is also not without limitations. One such limitation is that the present study did not statistically analyse aspects such as sex differences and motor skill development patterns with age. Whilst these aspects are commented upon, the main aim of the present study was to provide normative values for TGMD-3 scores using data from a very large European cohort. Given the conflicting literature on sex differences in motor skill development patterns, this warrants further investigation. Another possible limitation of this analysis is that only Italian children have been used. However, previous normative data for the TGMD-3 were from USA cohorts²³; thus, the present study is important in providing European norms. Future research should focus on collecting similar very large data sets from cohorts in several European countries; not only enabling comparisons between these cohorts to assess if there are any differences between different European countries, but also creating an even larger data bank of TGMD-3 scores.

5. Conclusion

Overall, the most important aspect of this investigation is the development of age- and sex-specific normative percentiles for TGMD-3 scores for over 17,000 Italian children aged 3–10+ years. The development of this normative data enables the identification of children who lack proficiency in motor skill development relative to their age and sex norms. Identification subsequently allows for timely and appropriate interventions to increase motor skill proficiency. This set of normative data can be used by a vast array of practitioners (including, but not limited to, healthcare professions, physical education teachers, and sports coaches) to identify insufficient motor skill development and thus intervene early to prevent motor skill incompetence and encourage mastery of each skill and ultimately foster the likelihood of lifelong physical activity.

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jsams.2024.12.013>.

CRediT authorship contribution statement

Grace W M Walters: Formal analysis, Writing – Original draft, Writing – Review & editing, Visualisation; Simon Cooper: Writing – Original draft, Writing – Review & editing, Visualisation, Supervision; Fabio Carlevaro: Conceptualisation, Ideas, Methodology, Investigation, Resources, Data curation, Supervision, Project administration, Funding acquisition; Francesca Magno: Conceptualisation, Ideas, Methodology, Investigation, Resources, Data curation, Supervision, Project administration; Ruth Boat: Writing – Original draft, Writing – Review & editing, Visualisation; Supervision Roberto Vagnetti: Data curation, Writing –

Original draft, Writing – Review & editing, Visualisation; Cristiana D'Anna: Writing – Original draft, Writing – Review & editing, Visualisation; Giovanni Musella: Supervision, Project administration, Funding acquisition; Daniele Magistro: Conceptualisation, Ideas, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – Review & editing, Supervision, Project administration, Funding acquisition.

Confirmation of ethical compliance

The ethical committee of the University of Torino approved the study (study ID 100949) all all methods carried out were done so in line with the approved methodology.

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Declaration of interest statement

The authors have no conflicts of interest to declare.

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