communications medicine

A Nature Portfolio journal

Article

https://doi.org/10.1038/s43856-026-01592-9

Measuring gross motor skills in African children using the PERF-FIT

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Abstract

Background Africa is facing a rising prevalence of non-communicable diseases (NCDs), driven by shifts in lifestyle and dietary habits. Children with delays in motor coordination are less likely to participate in physical activity, active play, and sports, placing them at increased risk for obesity, reduced physical fitness, and cardiovascular diseases. Existing motor performance tests for school-aged children were not designed for African populations and lack culturally valid normative data.

Methods As part of an African-led initiative, the PERFormance and FITness test battery (PERF-FIT) was developed to assess motor performance and motor skill-related physical fitness in children aged 6–12 years. The PERF-FIT test battery is open-source, contextually relevant, and tailored for low-resource settings. This study involved the collection of motor performance data from a large sample of African children to establish age- and sex-specific normative values.

Results This study generates normative data for motor skills in African children aged 6–12 years (n = 2604), stratified by age and sex. These norms complement the previously validated psychometric properties of the PERF-FIT, confirming its reliability and applicability across diverse African contexts.

Conclusions The PERF-FIT test battery provides a culturally appropriate and psychometrically sound tool for assessing motor performance in African children. It serves as a valuable resource for clinicians, educators, and policymakers to monitor motor skill related physical fitness and detect motor delays in children aged 6–12 years in African countries.

Plain language summary

This study aimed to make a motor performance test that is suitable for African children aged 6 to 12 years. Many existing tests were developed in other regions and do not reflect the abilities or context of African children. Researchers of an African-led initiative developed the PERFormance and FITness test battery (PERF-FIT), which is free to use and designed for schools, clinics and healthcare workers in low-resource settings. The study describes how data were collected from 2604 children to create age- and sex-specific norms. These results help professionals understand what typical motor skills look like in African children. This tool can support early identification of children at risk for motor delays and health problems based on low motor fitness.

Africa is home to the world's largest pediatric population, yet it bears a disproportionate burden of health challenges (https://diabetesatlas.org/data/en/indicators/22/). According to the World Health Organization (WHO), the continent accounts for 25% of the global disease burden but receives less than 1% of worldwide health expenditures (https://www.un.org/africarenewal/magazine/december-2016-march-2017/health-care-commitments-action). One of the growing concerns in Africa is the increasing prevalence of non-communicable diseases (NCDs), due to shifts in lifestyle and unhealthy dietary habits[1,2]. Early intervention, particularly through physical activity promotion, has emerged as a key strategy in preventing NCDs and fostering positive health outcomes over the long-term[3]. A critical yet often overlooked factor in promoting physical activity among children is gross motor skill competence, encompassing locomotor skills (e.g., running, hopping and jumping), object manipulation skills (e.g., bouncing and throwing) and body coordination (e.g., balance control)[4,5]. Children with less-developed motor skills are less likely to participate in

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physical activities and less inclined to engage in active play or sports[6,7]. The lack of physical activity can ultimately lead to decreased physical fitness, which is a major risk factor for many NCDs[5,8].

While much of the focus on physical activity has centered on promoting exercise in adult populations, less attention has been given to the critical role motor skill competence plays in shaping children's long-term physical activity behavior, particularly in Africa[5](https://www.who.int/news-room/fact-sheets/detail/physical-activity). Early development of motor skills not only enhances children's ability to engage in physical activity but also plays a fundamental role in their cognitive development, social integration and overall health[9]. In school-aged children, motor skill competence serves as a critical determinant of self-perceived competence, physical fitness, and continued engagement in physical activity[10]. Initiatives such as the Global Matrix Report Card, which synthesizes national evidence on topics related to physical activity and the health of children and adolescents, have shown a lack a nationally representative data on physical activity and healthy eating among South African children[11]. Unfortunately, children in many African countries face significant barriers to developing the essential motor skills needed to be physically active[12].

In general, at a young age, African children seem to develop faster than their Western peers, probably caused by common practices of African mothers, which promotes and supports the development of young infants[13]. However, not all children develop motor skills at the same rate, and various factors such as developmental disorders, HIV, sickle cell disease, and environmental constraints can further hinder motor development in many children in Africa[14]. Unfortunately, the lack of standardized and contextually relevant assessments makes it difficult to identify motor delays in this population early in life. In African contexts, most attention has been given to children under age five, due to increased mortality risk in this group caused by severe diseases (in combination with malnutrition). Several tests were adapted to the African contexts to support early identification of developmental delays[15–20]. However, after age five, mild motor difficulties may become apparent, significantly impacting a child's overall functioning and well-being, as seen in conditions such as Developmental Coordination Disorder. Western guidelines recommend the use of standardized norm-references tests such as the Movement Assessment Battery for Children, second edition (MABC-2) or the Bruininks-Oseretsky Test of Motor Performance, second edition (BOT-2) to identify these mild motor difficulties[21].

A major problem is that these tests were developed for Western societies and therefore have normative data for children in those contexts. None of these assessments have valid norms for African children[22]. Existing data on motor performance in African children often paints a conflicting picture, with higher-than-expected percentages of school-aged children classified as at risk or severely impaired when assessed on either the MABC-2 or BOT-2[23–28]. In contrast, fewer African children were identified as being at risk with the TGMD-2[19]. These findings highlight the inadequacy of applying Western derived norms to the African context[28,29]. Moreover, most of these Western assessments are prohibitively expensive for widespread utilization in low-resource areas[22], further emphasizing the need for more accessible, validated and culturally appropriate assessments in such settings. Developing culturally appropriate assessments to support population-level evaluation of motor skills and skill-related physical fitness competence among children in these communities is merited.

To address this gap, we developed the PERFormance and FITness (PERF-FIT) test battery—a motor performance assessment specifically designed for use in low-resource settings. Physical fitness is commonly divided into two broad categories: health-related fitness and skill-related fitness. Health-related fitness includes cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition[30]. Skill-related fitness, on the other hand, encompasses the components necessary for an individual to successfully demonstrate a variety of motor skills, and it is the construct we aimed to measure with this test[31].

The development of the PERF-FIT followed a multi-phase process: 1) Initial conceptualization: informed by experts' recommendations (educators and clinicians from many universities across low-income countries). 2) Item selection and pilot testing: emphasizing feasibility and cultural relevance in low-income settings. 3) Psychometric evaluation: over ten studies have evaluated content and construct validity, interrater and test-retest reliability, responsiveness, and cross-cultural applicability. Psychometric studies have shown that the PERF-FIT test provides a set of feasible[31], reliable and culturally relevant items[31,32] that healthcare professionals and educators can use to evaluate motor skill development in children aged 6-12 years.

Developed with input from experts in child development and human movement science[31], and refined through feedback received during several rounds of presentations and workshops at conferences, and community engagement dialogues with clinicians and researchers (including physiotherapists and occupational therapists) working with children with motor disorders, the PERF-FIT test assesses key motor domains of motor skill-related fitness, such as agility, balance, coordination, power, reaction time, and speed within various motor skills (like running, throwing, hopping)—all of which are essential for fostering physical activity.

This collaborative effort has yielded a test that provides a free, open-source and accessible instrument that can be used to conduct motor skills assessments and guide interventions. The PERF-FIT test will empower communities across Africa to take proactive steps towards improving children's physical health, and by extension, their future well-being. By creating this resource, we aim to contribute to the United Nations' Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) and SDG 4 (Quality Education), while promoting a more equitable approach to addressing health disparities among African children(https://sdgs.un.org/goals). After showing feasibility, validity and reliability in our earlier works, this paper aims to establish normative data for the PERF-FIT test battery that are both age- and sex-appropriate for African children. By providing these norms, we aim to give clinicians and educators a tool to identify children at risk for motor delays or low motor skill related physical fitness to subsequently provide tailored interventions to improve physical health and active lifestyles.

This study establishes age- and sex-specific normative data for motor performance in African children aged 6–12 years, based on the identified age- and sex-related differences in a sample of 2604 children from five countries. The PERF-FIT test battery has strong psychometric properties and offers a culturally appropriate, open-access tool for assessing motor skill-related physical fitness in low-resource settings. These norms provide a valuable benchmark for identifying motor delays and monitoring developmental progress across diverse African contexts.

Methods

Selection of Participants

Data were collected from children across various countries and regions of Africa (Table 1). Specifically, data were sampled from Nigeria and Ghana in West Africa, Ethiopia in East Africa, Tunisia in North Africa (replacing Sudan due to the conflict), and South Africa in Southern Africa. Elementary schools were selected randomly from different socioeconomic areas with different degrees of urbanization (cities, municipalities, urban informal settlements -former townships, and rural areas). School principals signed goodwill letters to confirm their participation. Children (males and females), in the selected schools, who were between 6-12 years and were fit to participate in motor skill testing (as confirmed through parent reports or the Children's Physical Activity Readiness Questionnaire (C-PAR-Q)) were included in the study. Participants were excluded if they presented with 1) acute or chronic musculoskeletal injuries, 2) symptoms of acute illness (e.g., temperature>38/ flu symptoms), or had a history of reported chronic diseases such as asthma, cystic fibrosis.

Study procedure

This cross-sectional study was conducted between 2019 and September 2024. All data were anonymized and analyzed using unique ID numbers. Ethical approvals were granted by the respective Human Research Ethics Committees (South Africa: HREC REF: 139/2019, HREC REF: 112/2020, NWU 00491-19-A1; Tunisia: CPP SUD N° 0301/2021; Ghana: GHS-ERC 052/05/19; Nigeria: UUTH/AD/S/96/VOL/XXI/524; Ethiopia: JUIH/IRB/691/23). Permission was also obtained from local education authorities and school administrators. Written informed consent was secured from parents, while children provided assent. All procedures adhered to the World Medical Association Declaration of Helsinki (1964)[33]. The PERF-FIT test battery was administered by trained research staff who followed standardized protocols. Training included reading the manual, practicing with both typically developing children and children with neurodevelopmental differences, and receiving feedback on recorded or live demonstrations. Only after successful evaluations were the research staff cleared to conduct testing. All testing occurred in small groups at schools. During testing, children were allowed to wear school uniforms and perform the tests on barefoot.

Materials

Demographic and anthropometric data. Demographic data included age, sex, country, and region. Height was measured using a steel tape measure mounted on a wall, and weight was recorded using an electronic scale, both without shoes and in light clothing. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Children were classified into BMI categories based on International Obesity Task Force (IOTF) criteria[34]: thinness grades 1-3, normal weight, overweight, and obese.

PERF-FIT test battery. The PERF-FIT test battery targets children aged 6-12 years, including those suspected of low motor skills or physical fitness. It was designed to:

- Be culturally appropriate for children aged 6-12 years.
- Cover different aspects of motor skill-related physical fitness.
- Require no expensive materials or specific space requirements.

Motor skill-related fitness[35] encompasses the combination of the motor skills (like coordinated jumping, hopping, catching) and the power and agility components required to perform the skill within an activity or for a certain time. These components are particularly vital for children aged 6–12, as they form the foundation for developing fundamental movement skills. The test comprises 10 items (Table 2) divided into two subscales: 1) *Power and Agility Subscale* with several motor activities requiring high levels of explosive power (long jump, overhead throw) and agility (running, stepping, side jump) and 2) the *Motor Skill Performance Subscale* with a number of activities (including bouncing and catching, throwing and catching, jumping and hopping, static balance, and dynamic balance tasks) requiring high levels of coordination and postural control. Each item is described in detail in the manual (Supplementary Information 1). The test has a maximum administration time of 40 minutes and scoring is done automatically with excel sheets Supplementary Data 1 or 2. The test has been validated and deemed to have excellent content validity[31], good construct and concurrent validity[32,36–42], high inter-rater reliability (ICC = 0.99), good test-retest reliability (ICC = 0.80)[43], and captures change after intervention[44–46]. A detailed summary of the test's psychometric properties is provided in Table 3.

Data curation. Because extreme weight statuses are associated with poor motor performance[47,48], children with a BMI-for-age z-score of ≥−2 (classified as thinness grade 3), or ≥+2 (classified as obese) were excluded from the norm sample. This resulted in a final analytic sample of 2604 participants.

Data analysis

Descriptive statistics summarized demographic data, including age, weight, height, BMI, sex, and country. Raw PERF-FIT scores were examined for missing data and outliers. Q-Q plots indicated approximate normality for Power and Agility subscale items, while Motor Skill Performance subscale items exhibited increasing skewness with age, particularly for the balance tasks. Differences in raw scores by age group and sex, and their interaction effects were analyzed using ANOVA with post-hoc pairwise comparison with Bonferroni corrections. All tests were performed two-sided. Effect sizes (η^2) were interpreted as small (0.01-0.059), medium (0.06-0.13), or large (≥ 0.14)[49]. Internal consistency was assessed using Cronbach's Alpha.

Table 1 | Overview of Data Collection Sites in Africa (https://www.uneca.org)

Region	Country	Percentage of Africa	Total Population	Percentage Growth
North	Sudan[a]	3.4%	50,042,791	1.34%
	Tunisia	0.9%	12,200,431	0.67%
East	Ethiopia	8.7%	128,691,692	2.64%
West	Nigeria	15.4%	227,882,945	2.12%
	Ghana	2.3%	33,787,914	1.93%
South	South Africa	4.3%	63,212,384	1.34%

[a]No data could be collected because of the conflict.

Table 2 | Description of the PERF-FIT items per subscale

PERF-FIT	
Items	**Description**
Performance subscale	
Bouncing and Catching (#)	Children bounce a tennis ball to the floor and catch it. This series involves five bouncing and catching items of increasing skill difficulty.
Throwing and Catching (#)	Children throw tennis ball in the air to at least eye level height and catch it. This series involves five throwing and catching items of increasing skill difficulty.
Jump (cm)	Children are asked to jump inside an agility ladder. This series involves four jumping items of increasing difficulty.
Hop (#)	Children are asked to hop inside an agility ladder. This series involves four hopping items of increasing difficulty for each leg.
Balance (s/#)	Children are asked to perform two static balance tasks for each leg and three dynamic balance tasks. Dynamic tasks involve knee hugging, grasping the foot and picking up cans from the floor.
Agility and Power Subscale	
Running (s)	Children are asked to run (one foot per square) in 3.5 m agility ladder and run around a bottle placed at a distance of 50 cm and back.
Stepping (s)	Children step with two feet in each square of a 3.5 m agility ladder and run around a bottle placed at a distance of 50 cm and back.
Side Jump (#)	Children are required to jump sideways in the agility ladder. The total number of correct landings in 15 s is recorded.
Long Jump (cm)	Children are asked to jump forward as far as possible and land on their feet with a balanced landing.
Overhead Throw (cm)	Children kneel just behind a starting line and throw a sandbag (2 kg) forward as far as possible.

Table 3 | Summary of psychometric properties of the PERF-FIT test

RELIABILITY				RESPONSIVENESS
Internal consistency		Interrater reliability	Test-retest reliability	
		ICC = 0.99[43]	ICC > 0.80 CoV: 0-20% (excellent to good precision)[43]	Children with DCD: Medium-to-large effect sizes for all PERF-FIT items, except throw & catch, after a Wii-fit intervention (12 weeks, 3x/week)[45]. Medium effect sizes for the PERF-FIT stepping and side jump items after Wii-fit/Kinect training (5 weeks, 1-2x/week)[44]. Children with moderate thinness: Large improvements after active play intervention (12 weeks, 5x/week) on the stepping, side jump, long jump, bounce & catch, throw & catch and jumping & hopping[46].
VALIDITY				
Content	**Construct validity**			**Criterion/ concurrent**
	Structural	***Hypothesis testing***	***Cross-cultural***	
CVI score of 0.99[31]	Moderate correlations among PERF-FIT balance items[42]. Balance items load on one component indicating the same construct[42]. PERF-FIT ball skill items correlate strongly with each other and moderately with the overhead throw[39]. The PERF-FIT ball skill items load on another component than the overhead throw, supporting the distinct constructs they cover[39].	Children with DCD: children with severe DCD perform significantly poorer on the PERF-FIT bounce & catch, throw & catch and overhead throw items than individuals with moderate DCD, who perform significantly poorer than TD peers[37,38]. The PERF-FIT is moderately associated with the DCDDaily questionnaire total scores and daily participation subscore[38]. Malnourished children: overweight children perform significantly poorer on static and dynamic balance tasks than normal weight peers[40]. Underweight children perform significantly poorer on power items than TD peers[41].	The English manual has been translated for use in local languages.	Moderate correlations between PERF-FIT items and BOT-2 and MABC-2 balance items[42]. Moderate to high correlations between PERF-FIT items and exergames[36]. PERF-FIT ball skill items correlate moderately with BOT-2 ball skill items, but weakly with MABC-2 items[39].

CoV coefficient of variation, *TD* typically developing, *DCD* developmental coordination disorder.

Table 4 | Description of the sample

	Males		Females		
Years	Frequency[a]	Percentage	Frequency[a]	Percentage	
6	132	10.2	142	10.9	
7	277	21.3	253	19.4	
8	257	19.8	244	18.7	
9	208	16.0	215	16.5	
10	196	15.1	199	15.2	
11	146	11.2	160	12.3	
12	82	6.3	93	7.1	
Total	1298	100.0	1306	100.0	
	Ethiopia	**Ghana**	**Nigeria**	**South Africa**	**Tunesia**
Males/Females[a]	149/117	237/242	147/153	641/668	124/126
Age (years)[b]	6.8 (0.5)	9.81 (1.8)	8.2 (1.5)	9.5 (1.7)	8.5 (1.5)
BMI (kg/m²)[b]	13.80 (1.26)	16.35 (2.34)	15.31 (2.19)	16.52 (2.27)	17.14 (1.89)
Height (m)[b]	1.17 (0.08)	1.38 (0.12)	1.27 (0.10)	1.34 (0.11)	1.30 (0.09)
Weight (kg)[b]	19.1 (2.46)	31.73 (8.54)	24.97 (6.62)	30.22 (8.06)	29.13 (6.13)

[a]Number of children.
[b]Mean (SD).

Table 5 | Main effects, based on the ANOVA, for Age and Sex on the 10 PERF-FIT Items and interactions

	Main Effect Age	Main Effect Sex	Interaction Effect
Running	$F_{6,2581} = 272.962$, **$p < 0.001$**; η^2=0.388	$F_{1,2581} = 5.447$, **$p = 0.020$**; η^2=0.002[a]	$F_{6,2581} = 0.485$, $p = 0.820$; η^2=0.001
Stepping	$F_{6,2566} = 266.265$, **$p < 0.001$**; η^2=0.384	$F_{1,2566} = 1.318$, $p = 0.251$; η^2=0.001	$F_{6,2566} = 0.672$, $p = 0.673$; η^2=0.002
Side jump	$F_{6,2557} = 346.015$, **$p < 0.001$**; η^2=0.448	$F_{1,2557} = 25.243$, **$p < 0.001$**; η^2=0.010[b]	$F_{6,2557} = 0.484$, $p = 0.821$; η^2=0.001
Long jump	$F_{6,2583} = 215.595$, **$p < 0.001$**; η^2=0.334	$F_{1,2583} = 73.005$, **$p < 0.001$**; η^2=0.027[a]	$F_{6,2583} = 1.913$, $p = 0.075$; η^2=0.004
Overhead throw	$F_{6,2587} = 442.914$, **$p < 0.001$**; η^2=0.507	$F_{1,2587} = 67.964$, **$p < 0.001$**; η^2=0.026[a]	$F_{6,2557} = 1.482$, $p = 0.180$; η^2=0.003
Bounce & catch	$F_{6,2583} = 198.662$, **$p < 0.001$**; η^2=0.316	$F_{1,2583} = 39.662$, **$p < 0.001$**; η^2=0.015[a]	$F_{6,2583} = 0.896$, $p = 0.497$; η^2=0.002
Throw & catch	$F_{6,2583} = 194.539$, **$p < 0.001$**; η^2=0.311	$F_{1,2583} = 38.465$, **$p < 0.001$**; η^2=0.015[a]	$F_{6,2583} = 2.071$, $p = 0.054$; η^2=0.005
Static balance	$F_{6,2562} = 41.666$, **$p < 0.001$**; η^2=0.089	$F_{1,2562} = 7.647$, **$p = 0.006$**; η^2=0.003[b]	$F_{6,2562} = 2.405$, **$p = 0.025$**; η^2=0.006
Dynamic balance	$F_{6,2579} = 104.489$, **$p < 0.001$**; η^2=0.196	$F_{1,2579} = 5.386$, **$p = 0.020$**; η^2=0.002[b]	$F_{6,2579} = 1.547$, $p = 0.159$; η^2=0.004
Jumping & hopping	$F_{6,2583} = 88.426$, **$p < 0.001$**; η^2=0.170	$F_{1,2583} = 0.998$, $p = 0.318$; η^2=0.000	$F_{6,2583} = 1.265$, $p = 0.270$; η^2=0.003

Bold values indicate significant differences $p < 0.05$.
[a]Males outperform females.
[b]Females outperform males.

Development of reference norms

Raw scores were transformed into z-scores per age group and sex, following a Standard Normal Distribution (mean = 0, SD = 1). Z-scores for items where lower scores indicated better performance (e.g., running and stepping) were reversed. Z-scores allow for comparisons across items and age groups by standardizing scores to a common scale. Outliers (± 4 SD) were excluded. Missing data for static balance item of Tunisia were replaced by the mean for age and sex.

Z-scores were further converted into scaled scores (range: 1-19; mean = 10, SD = 3) and percentiles. Scaled scores were used to classify motor skill levels: typical development (≥8), below average (5-7), and definite difficulties (≤ 4). Percentiles were calculated for clinical interpretation, providing a measure of relative position within the reference group. All analyses were performed using SPSS (version 30.0; IBM Corp., Armonk, NY) at a significance level of $p < 0.05$.

Results

Sample

The entire sample consisted of 2817 children, Nigeria (n = 336) and Ghana (n = 511), Ethiopia (n = 312), Tunisia (251), and South Africa (n = 1407). Of the total sample 102 (3.6%) were excluded because of thinness level 3 and 111 (3.9%) because of obesity. The PERF-FIT results of the remaining 2604 children (BMI, mean: 16.13, SD: 2.34) were used to calculate the norm scores. This sample consisted of 21.1% children who were underweight, 67.9% having normal weight, and 11.0% overweight. Both sexes were represented equally: half males (49.8%) and half females (50.2%). The age range of the norm sample was 6-12 years (mean: 8.7 years, SD:1.8). The age distribution per sex is shown in Table 4.

Age and sex-based effects

Results of the ANOVA showed a significant large age effect across all PERF-FIT items ($p < 0.001$), except for static balance, which showed a medium sized effect (Table 5). Figure 1 illustrates the magnitude of age differences in effect sizes.

Pairwise comparisons between consecutive age groups revealed significant differences ($p < 0.01$ after Bonferroni correction) for each comparison except Running 11-12, Stepping 6-7, 9-10, 11-12, Side jump 6-7, Long jump 10-11, Bounce and catch, and Throw and catch, 11-12, Static balance 8-9, 9-10, 11-12, Dynamic balance 8-9, 9-10, 11-12, Jumping and Hopping 7-8, 10-11 and 11-12years.

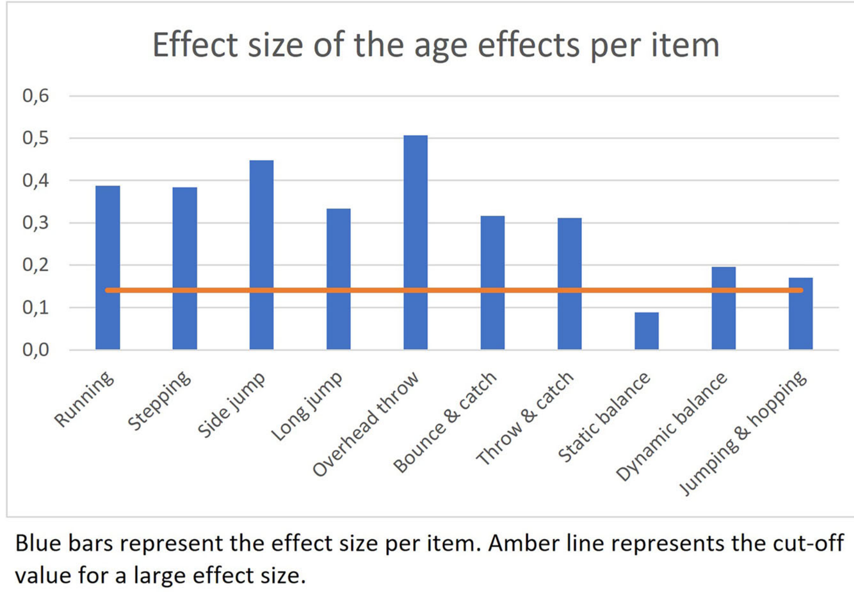

Fig. 1 | Effect sizes of the age effects per item. Line indicates $\eta^2 \geq 0.14$ or large effect size.

Table 6 | Classification of the Scaled Score and Percentiles

Scaled score	Classification of performance	Percentile
1–4	Well below average	≤ 2
5–7	Below average	5–16
8–12	Typical Development	25–75
13–15	Above average	84–95
16–19	Well above average	≥ 98

Sex-based effects were also observed, with the direction of effects varying by task. Males outperformed females in upper ($p < 0.001$) and lower extremity ($p < 0.001$) power tasks and ball-related items ($p < 0.001$), while females excelled in side-jump ($p < 0.001$) and balance tasks ($p = [0.006, 0.020]$). However, these sex-based differences had small effect sizes (Table 5).

Reliability

Internal consistency evaluation showed a Cronbach's Alpha of 0.74, suggesting good internal consistency.

Reference norms

Age- and sex-specific norms are presented as scaled scores per item, per subscale and total scores. An application is provided, which will calculate these scales scores after entering the raw scores in Excel files (Supplementary Data 1 for Windows format; Supplementary Data 2 for Mac users). Additionally, a look up table for the scale scores is provided as Supplementary Data 3. Supplementary information 2 provides instructions how to fill out the Excell sheet. Interpretation guidelines for these scaled scores are outlined in Table 6. Scaled scores of 8 and higher indicate typical development and scaled scores of ≤4 point to definite motor difficulties. The age-and sex-specific normative data are exemplified through the side jump and the cans task (dynamic balance) in Figs. 2–5. The number of side jumps in 15 seconds increases significantly with increasing age in both males and females as shown in Figs. 2 and 3. Females outperform males in each age band. In Figs. 4 and 5 a clear ceiling effect is visible for the children with good performances (percentile curve 50 and 85), whereas those with lower scores improve with increasing age.

Discussion

Africa has the youngest and fastest-growing population in the world, and yet no motor performance tests with reference norms are available for school aged children in this region. This lack of standardized tools limits detection and intervention of motor deficits, particularly in low-resource settings. Recognizing this gap, we developed the Performance and Fitness (PERF-FIT) test battery, a contextually relevant, a freely available, reliable, and valid low-cost tool tailored to low-resource communities[31,32,36,38–41,43–45].

The normative data generated in this study provide an appropriate benchmark for assessing motor performance in African children and monitoring change over time. Our overarching goal was to capture a range of motor development patterns across different African contexts, with an emphasis on motor performance levels that children typically master at different ages, rather than to create a continent-wide representative sample. We believe our sample provides a strong starting point for more inclusive and relevant normative data and acknowledge the need for continued expansion across other African regions in future work. While our normative data were drawn from five African countries—more heavily weighted toward South Africa—we focused on capturing diversity within and across sites, including both urban and rural communities. In South Africa, we used school quintiles as a proxy for socioeconomic status (SES), while in other countries, standardized SES measures (e.g., parental education or income) were unreliable due to high informal employment, illiteracy, and contextual differences in school infrastructure. For instance, in many areas, "urban" may include informal settlements (former townships) with minimal access to water or electricity, conditions not typically associated with urban settings in high-income countries.

Given these constraints, we relied on observable school infrastructure, rural/urban classifications, and engagement with local communities to ensure diversity within our sample. Our goal was to build a more culturally and environmentally relevant normative baseline for motor development in African children—not to generalize to all regions, but to improve upon the inappropriate application of Western norms in African populations.

Our findings confirm the necessity of age- and sex-specific norms for motor performance assessments. Age differences were highly significant for all components of the PERF-FIT, underscoring the importance of accounting for developmental progress in motor skills and skill related fitness. Although sex differences were small, they were task-dependent: males outperformed females in tasks involving upper and lower extremity power and ball skills, while

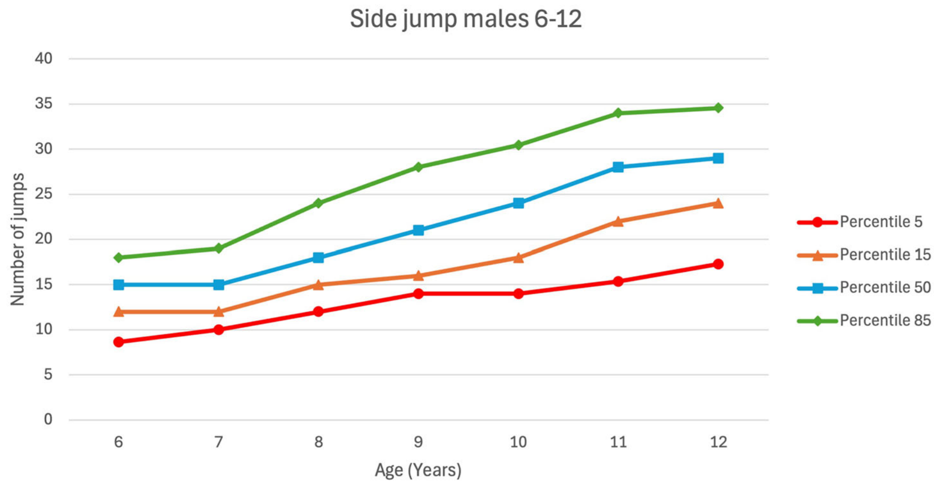

Fig. 2 | Example of the percentile curves for the 5th, 15th, 50th, and 85th percentiles for side jump across different age groups for males. Green diamonds and lines represent percentile 85. Blue squares and lines represent percentile 50. Amber triangles and lines represent percentile 15. Red circles and lines represent percentile 5.

Fig. 3 | Example of the percentile curves for the 5th, 15th, 50th, and 85th percentiles for side jump across different age groups for females. Green diamonds and lines represent percentile 85. Blue squares and lines represent percentile 50. Amber triangles and lines represent percentile 15. Red circles and lines represent percentile 5.

females excelled in agility and balance tasks, which is consistent with literature trends[47]. Despite the small effect sizes, we opted to present sex-specific norms - which is consistent with other norm-referenced tests[22], to minimize the risk of misclassification, particularly in clinical or educational settings as evidenced by our previous research[50].

The age- and sex-specific norms presented in this study represent a significant step forward in the assessment of motor skills and physical fitness in African children. Scaled scores or percentile-based evaluations allow clinicians and educators to identify children at risk of motor deficits or fitness concerns (Supplementary Data 1–3). For instance, children scoring below the 5th percentile may require further evaluation or targeted intervention. Because children in different circumstances perform a variety of more or less physically demanding tasks on a daily basis, small differences in development at the individual level are to be expected. At the group level, these norms can guide policy and practice, such as designing interventions to improve physical activity opportunities in schools or communities.

By identifying specific areas of need, schools can introduce active recess initiatives or create safe spaces for active play. Similar to other existing pediatric motor skill assessment tools[22], individualized or small-group interventions can be developed to address specific deficits in children consistently scoring in the impaired range.

The PERF-FIT offers a context-appropriate alternative to traditional motor assessments and can help establish population-level motor performance. Moreover, skill related physical fitness aligns well with international and continent-level initiatives measuring and promoting health-related fitness and physical activity (e.g., Global Matrix, AFPAN).

It is important to caution clinicians and other users that even with the large sample size of 2604 children the normative data for the PERF-FIT test are based on relatively small sample sizes (min 82- max 277) for each sex age group. This has implications for the reliability of scores at the extreme ends of the distribution. For example, consider a sample of 100 six-year-old boys. Using a standard score distribution approximately 68% of these children—roughly 68 individuals—would be expected to fall within the normal range (mean = 10, SD = 3 or between 17-84 percentile). This leaves only about 32 children distributed across the lower and upper extremes. More critically, scores that fall into the impaired range (e.g., scaled scores of 1 to 4) would represent a very small subset of the total age and sex sample (3 or 4 children). As a result, the normative power of scores around the middle of the distribution (standard scores 8-12) will be very stable and while stability of low-end scores is more limited, and users should interpret such scores with caution. Although these limitations are important in the context of presenting norms in this manner, it is essential to recognize that existing Western norming studies of motor test batteries—such as the MABC-2, BOT-2, and TGMD-3—have employed similar methodologies. Some of these standardization studies have even included smaller group sizes which increases the potential for measurement error or misclassification. Test scores should never be used in isolation for clinical decision-making.

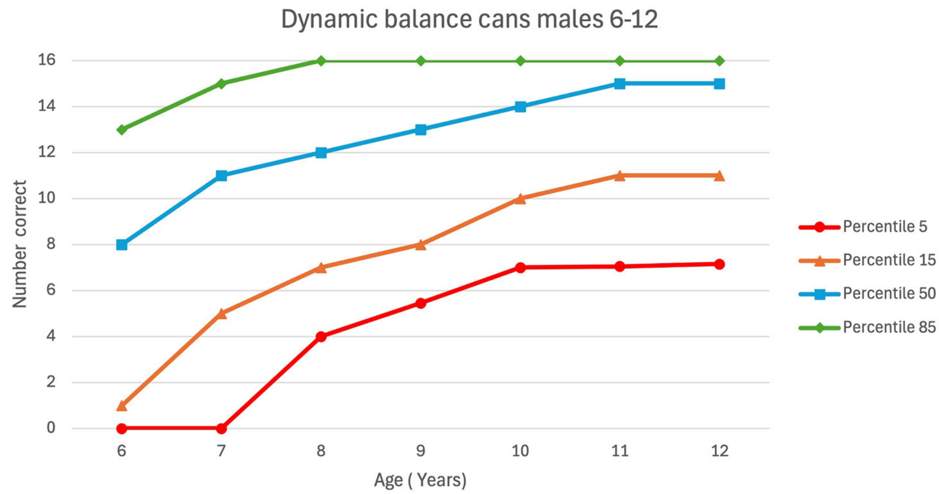

Fig. 4 | Example of the percentile curves for the 5th, 15th, 50th, and 85th percentiles for cans task across different age groups for males. Green diamonds and lines represent percentile 85. Blue squares and lines represent percentile 50. Amber triangles and lines represent percentile 15. Red circles and lines represent percentile 5.

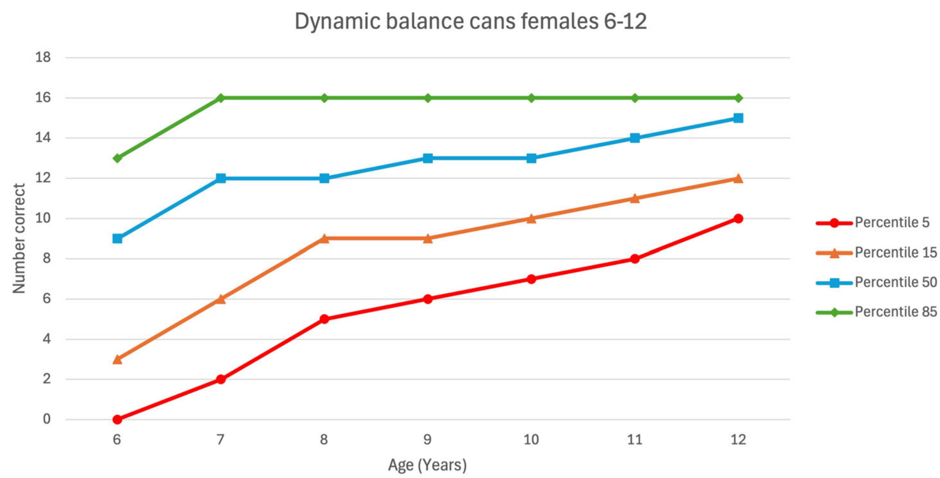

Fig. 5 | Example of the percentile curves for the 5th, 15th, 50th, and 85th percentiles for cans task across different age groups for females. Green diamonds and lines represent percentile 85. Blue squares and lines represent percentile 50. Amber triangles and lines represent percentile 15. Red circles and lines represent percentile 5.

One of the strengths of the PERF-FIT test battery is that it was rigorously evaluated against the COnsensus-based Standards for the selection of health Measurement Instruments (COSMIN)[51]. Studies of its psychometric properties demonstrated high inter-rater reliability, test-retest stability, internal consistency and strong content validity, with tasks reflecting culturally relevant activities and daily physical demands[31,32,37–46]. Also, our norm group is at least twice as large as in the EACD guideline recommended tools to identify children with mild motor difficulties[21]. While criterion validity could not be directly established due to the lack of comparable tools in African populations, the PERF-FIT showed moderate correlations with existing tools used in other contexts[36,39,42]. These findings underscore the robustness of the PERF-FIT as a valid and reliable assessment tool (see Table 3).

While our normative data were drawn from 5 out of 54 African countries—with a larger portion from South Africa—we aimed for diversity within those samples, rather than statistical representativeness across the entire continent. Our intention was to provide a more contextually relevant and culturally informed alternative to existing norms developed in high-income, Western countries. We acknowledge that South Africa was more heavily represented primarily due to logistical feasibility and established research partnerships, which allowed for controlled data collection, access to approved school systems, and inclusion of both urban and rural participants across a wide socioeconomic spectrum. We used school quintiles as a proxy for socioeconomic status (SES) in South Africa, while in other countries such as Ethiopia, Ghana, and Nigeria, formal SES markers like parental education, income, or occupation proved unreliable due to factors such as high levels of informal employment or self-employment (e.g., "merchant" as a catch-all term), illiteracy, especially in rural areas, and cultural sensitivities. Moreover, in these settings, access to education, geographic setting (rural vs. urban/township), and observable school infrastructure became more meaningful proxies. Nevertheless, we fully acknowledge that many key variables such as availability of physical education, sport opportunities, parental education, and socioeconomic status (SES) — are complex and not uniformly measurable across countries. We recognize the need for future studies to expand this work across more countries and contexts.

Although the PERF-FIT norms were developed from a large sample, the exclusion of children with severe underweight and obesity limits their applicability to extreme BMI categories. Yet, excluding children who are severely underweight or obese from the normative sample is a common and justifiable practice in test development, particularly when the goal is to establish reference norms for the general population. Severe undernutrition (> 2 SD below the norm for BMI-for-age) or obesity (> 2 SD above the norm) are known to significantly impact motor performance, potentially skewing the representativeness of norms for the general child population. However, underweight remains highly prevalent in parts of Africa; the African continent houses a third of the global "underweight" population, a staggering 33 million vulnerable individuals[52]. Therefore, further research is needed to explore the impact of weight on PERF-FIT outcomes in these populations. At present, moderately underweight children appear to be outperformed by normal weight peers, in a manner similar to overweight and obese children. In both groups, the severity of the weight deviation appears to be a determining factor and not motor skill level, although this requires further research. Children with severe thinness or obesity represent at-risk groups for motor development delays and should be considered separately when interpreting test outcomes in clinical or public health contexts. Additionally, ceiling effects were observed in some items, particularly balance tasks, among older children. However, this is consistent with similar motor performance tests developed in Western countries like the MABC-2 and BOT-2. Future studies should explore adaptations to reduce ceiling effects and evaluate the applicability of PERF-FIT norms in other populations and age groups (5-year-olds).

Conclusion

This study provides the age- and sex-specific motor skill norms for African children aged 6-12 years using the recently developed PERF-FIT test battery. The high percentage of children scoring in the impaired range in our earlier studies[26,28] highlighted the importance of contextually relevant assessment tools in addressing motor deficits and guiding interventions in low-resource settings. After having established robust psychometric properties, we have now generated normative data, which positioned the PERF-FIT test as a critical resource for clinicians, educators, and policymakers to detect and monitor motor performance among African children.

Data availability

All data generated or analyzed during this study are included in this article (and in the supplementary data files). The source data for Figures are provided in Supplementary Data 3. no funding was received for this project.

Received: 3 June 2025; Accepted: 8 April 2026;
Published online: 30 April 2026

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Acknowledgments

We acknowledge the support of parents, children, and management of the participating schools. Special thanks to the teams which helped out with the pilot studies (dr. Dorothee Jelsma, dr. Tatiane Targino Gomes Draghi, dr. Jorge Cavalcante Neto, dr. Gillian Ferguson). Also many thanks to the PhASRec team at North West University and all volunteers who helped collecting data, translate materials, enter data. Lastly, we thank Mark van Steen for developing the applications for automatically scoring the PERF-FIT.

Author contributions

BSE contributed to the conception/design of the total project. BSE and EV conceptualized the paper and analyzed the data. DC, RXDA, OAI, FF, YMD organized the projects in the different regions and supervised data acquisition and data entry of all local data. All authors critically evaluated the interpretation of the data and commented on the drafts of the manuscript. All authors read and approved the final manuscript.

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/s43856-026-01592-9.

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Peer review information Communications Medicine thanks Maria W. G. Nijhuis-van der Sanden and the other, anonymous, reviewer for their contribution to the peer review of this work. A peer review file is available.