RESEARCH ARTICLE

Gross motor skills trajectory variation between WEIRD and LMIC countries: A cross-cultural study

Nadia Cristina Valentini1*, Glauber Carvalho Nobre2, Marcelo Gonçalves Duarte3

1 Department of Physical Education, Physiotherapy, and Dance, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil, 2 Department of Physical Education and Sports, Instituto Federal do Ceará, Fortaleza, Ceará, Brazil, 3 Department of Physical Education, Universidade Federal do Mato Grosso do Sul, Corumbá, Brazil

* nadia.cristina@ufrgs.br

Abstract

Aim

This study aimed to examine the prevalence of delays and borderline impaired performance for Brazilian girls and boys and the differences in the motor trajectories (locomotor and ball skills) of girls and boys (3- to 10-years-old) across WEIRD (Western, Educated, Industrial, Rich, and Democratic) countries and Brazil—a low- and middle-income country (LMIC).

Methods

We assessed 1000 children (524 girls; 476 boys), 3- to 10.9-year-old (M = 6.9, SD = 2.1; Girls M = 6.9, SD = 2.0; Boys M = 6.9, SD = 2.1), using the Test of Gross Motor Development-3. Using systematic search, original studies investigating FMS in children using the TGMD-3 were eligible; 5 studies were eligible to have the results compared to the Brazilian sample. One sample t-test to run the secondary data from Irish, American, Finnish, and German children (i.e., mean, standard deviation).

Results

The prevalence of delays and borderline impaired performance was high among Brazilian girls (28.3% and 27.5%) and boys (10.6% and 22.7%). The cross-countries comparisons showed significant (p values from .048 and < .001) overall lower locomotor and ball skills scores for Brazilian children; the only exceptions were skipping, catching, and kicking. We observed stability in performance, across countries, after 8-years-old, and no ceiling effects were found in the samples.

Conclusions

The Brazilian sample emphasized the need for national strategies to foster children’s motor proficiency. Differences in motor opportunities may explain the differences in motor trajectories between children in WEIRD and LMIC countries.
During childhood, motor proficiency is hugely variable from child to child. Differences in individual characteristics (e.g., body mass index, age, sex [1–5]; and opportunities to practice skills [6–10] are often reported as relevant factors in those disparities. In addition, caregivers support [11, 12], population density [4], cultural environment [13–15], geographic regions [14, 16, 17], and socioeconomic status [16, 18, 19] also affect children’s motor proficiency.

Motor proficiency is also variable across countries due to cultural experiences; the evidence was reported for Belgium and Australia [20]; the United States [18, 21] and Greece [8]; Portugal and the United States [22]; and Greece, Italy, and Norway [23]. Of these studies, D’Hondt et al. [8] provided evidence that Belgium and Greek preschool children had similar gross motor proficiency. Bardid and colleagues [21] reported that Belgian children scored higher in three motor tasks (i.e., jumping, moving sideways, hopping) than 6- to 8-years-old Australian children and lower in object control skills than the 3- to-7-years-old American children. The authors suggested that differences in physical education programs in European countries and across continents related to sports practice—specifically in striking with a bat and overarm throwing—play an essential role in the results.

Regarding cross-cultural comparisons among WEIRD (Western, Educated, Industrial, Rich, and Democratic) and LMIC (Low- and Middle-Income Countries) countries, the literature is more robust regarding young ages (i.e., infants and toddlers). Overall higher gross motor scores are reported for Canadians [15, 24–26] and Greek [15] infants compared to Brazilians; and American and German compared, respectively, to Malawian [27] and Cameroonian Nso [28] infants. These results indicate culturally specific differences concerning tests tasks—infants perform higher in the tasks closer to their familiar experiences, parental beliefs regarding childrearing, and opportunities for movement explorations [15, 24, 25, 27–29].

For preschoolers and school-age children, one recent study compares the motor proficiency of children (4 to 11 years old) from the south of Brazil and Portugal. Brazilian boys’ scores were above Portuguese normative values in four out of six tasks (i.e., long jump, kick and throw velocity, shuttle run), and Brazilian girls performed below those values in all but one task (i.e., long jump). The authors suggested that differences in the physical education curriculum, children’s free time, and opportunities may explain these results [30]. These results are, to some extent, not expected since previous research reported a high prevalence of delays among Brazilian children [19, 31–36], in studies with included larger samples and several states. Overall, the delays have been related to socioeconomic restrictions [31, 32, 36, 37] and the consequently limited resources at home [38] and schools [14] to meet the children’s motor developmental needs.

These previous differences across countries were established using mostly the TGMD-2. To the authors’ knowledge, no studies also compared the children’s motor proficiency across countries using the TGMD-3. The TGMD-3 has included two new skills—skip and one-hand strike, besides two skills (two-hands strike and kick) that have been part of the assessment since its early version. These four skills could present a more robust cultural component interfering with the childhood motor trajectories—the practice of specific sports. The one-hand strike is practiced in tennis, although an increasing number of younger children has become involved with this sport, it mainly occurs in the United States and European countries [39]; in Brazil, the sport is still elitist with a high cost to participate [40]. Consequently, Brazilian children are less exposed to the practice of this skill. In addition, the two-hands strike, and the kick are highly practiced in the United States and Latin American countries, respectively, due to the baseball/softball and soccer culture; if it transfers to a different motor trajectory it is not known.
The opportunities for children to become motor proficient (e.g., physical education curriculum, engagement in physical education lessons, and enrollment in after-school sports programs) in WEIRD countries are not like the one found for children in the LMIC(s); nor are the results of research in WEIRD countries directly translate to children living in other contexts. Cross-cultural information is relevant to promoting motor proficiency, physical activity, and health outcomes among children [8]. Furthermore, comparing the gross motor skills trajectories across a wide age range for boys and girls from WEIRD and LMIC countries may provide new insights to understand the periods of maximum acquisition and stability in children’s performance in different cultures. This information may be essential to promote motor activity engagement across childhood and support the development of policies for monitoring motor proficiency and delays among children—common goals for researchers in different countries but highly relevant for low-income populations.

Moreover, a large population-based study that enrolled preschool and school-age children of a wide range of ages and from all regions of Brazil can lead to a deep comprehension of motor proficiency and the prevalence of motor delays in children. Specifically, the large age band could better represent the periods that occur more discontinuity in motor development, allowing for specific strategies to prevent the high rates of delay reported previously; and the enrollment of all regions could provide representatives regarding cultural differences in a continental country. Therefore, this study aimed to examine the prevalence of delays and borderline performance for Brazilian girls and boys and the differences in the motor trajectories (locomotor and ball skills) of girls and boys (3- to 10-years-old) across WEIRD countries and an LMIC country—Brazil. These objectives were grounded on the understanding that the identification of children with delays and borderline performance in LMIC(s) is crucial to providing adequate care and that cross-cultural research across European, North American, and Latin American countries would illustrate the range of cultural variation of motor practices that could affect motor trajectories. Besides, grounded on the knowledge that differences in culture influence how children acquire and practice motor skills, the age and sequence in which children acquire them, and the subsequent developmental trajectory [41], this study examined the variation in the trajectories at a particular skill for girls and boys across the countries.

Methods

This study was a part of a national study on children’s gross motor skills performance, and it is organized into two sections: a systematic review and a field study with Brazilian children.

Systematic review: Procedures and data extraction

We included studies using a systematic search procedure to select the studies for the countries’ comparisons. All the original studies investigating fundamental motor skills in children using the TGMD-3 were eligible. We used the PECOT (Population, Exposure, Comparing, Outcome, and Type of study) following the PRISMA protocol as an auxiliary method to include studies [42]. Therefore, we included studies conducted with children from 3- to 10-years-old (Population) assessed with the TGMD-3 (Exposure) and that present results for locomotor and ball skills (Outcome) reported in observational peer-reviewed journals (Type of study). Besides, we included the TGMD-3 manual (US sample). We excluded studies that did not report locomotor or ball skills scores according to age and sexes, at least in three age groups. Fig 1 presents the PRISMA flow diagram for the systematic review.

Following the PRISMA protocol, we conducted a computerized search using Web of Science, MEDLINE (accessed by PubMed), and Scopus databases. We utilized the logic-based
specific descriptors, Boolean operators (AND & OR), and parentheses. We used the following combination of keywords to locate studies from database inception to September 2020: "children" AND "child" or "childhood," AND "fundamental motor skill" OR "fundamental motor skills" OR "fundamental movement skills" OR "fundamental movement skill" OR "motor ability" OR "motor competence" OR "motor proficiency" OR "movement skills" OR "movement skill" AND "test of gross motor development third edition" OR "TGMD-3". We did not add filters (e.g., language, publication date, target audience).

We conducted the exportation of the articles with the Medline, Ris, and Bibtex extensions. We imported the data using the software for systematic review StArt (State of the Art through
Systematic Review) to identify duplicated, exclusion, and inclusion articles. Two co-authors (MGD and GCN) conducted this procedure. Studies’ titles and or abstracts retrieved using the search strategy and those from additional sources were screened independently by two authors (MGD and GCN) to identify studies that potentially meet the inclusion criteria; the same co-authors retrieved and independently assessed the studies for full eligibility. We solved the disagreements over the eligibility of studies by a third reviewer (MSS). Finally, we removed the duplicated studies and those that failed to meet inclusion criteria.

Through database researching we identified 157 papers (Web of Science = 26; Scopus = 103; Pubmed = 28). After removing 37 duplicates, we screened 120 studies by title and abstract, 61 studies were eligible for full-text screening. After the full-text screening, four articles matched the review criteria. Besides, we included the TGMD-3 manual manually. Thus, we included five studies conducted within the last five years—all developed economies (Germany, Finland, Ireland, and the United States), besides Brazil’s present study.

The samples included children from Germany [43], Finland [4, 44], Ireland—study 1 [3] and study 2 [2], and the United States—US [45]. The German study did not include the stationary two-hands strike in ball skills. The study 2 on Irish children did include a new locomotor skill, the vertical jump [2]. Therefore, we did not include the German study’s ball skills scores [43] and the locomotor scores from the Irish study 2 [2]. We extracted the selected studies’ locomotor skills and ball skills means and standard deviations. Therefore, we conducted the study across two mainly diverse contexts, Brazil—an LMIC country, and compared the Brazilian data with five WEIRD countries.

Field study: Participants, instruments, procedures, and data analysis

Participants. Participants were 1000 children (girls n = 524; boys n = 476), 3 to 10.9 years old (M = 6.9, SD = 2.1; Girls M = 6.9, SD = 2.0; Boys M = 6.9, SD = 2.1), residing in five main geographic regions of Brazil (North, Northeast, Central-West, Southeast, and South) including eight states (Amazonas, Pará, Ceará, Goiás, Mato Grosso do Sul, Minas Gerais, Santa Catarina, Rio Grande do Sul), ten cities, and 22 schools (public and private). The sample size was calculated in EpilInfo statistical software (version 7.0), considering an approximate population of 800,000 children, an expected 50% frequency, a design effect of 1.5, a 95% confidence level, an 4% acceptable margin of error, and 10 to 15% of possible losses. A final estimated sample necessary was between 990 and 1035 children. The sample was representative of the Brazilian population regarding the children attending public (92%) and private (8%) schools, (b) children attending pre-school (3 to 5 years old: 41%), and fundamental-school (6 to 10 years old: 59%), (c) family’s socioeconomic status (SES) (approximately 10% middle-high and high, 30% middle, and 60% middle-low and poor), (d) children’s biological sex (girls 52.4%; boys 47.6%), and country regions [46]. The exclusion criterium was children with disabilities (i.e., cerebral palsy, motor disorders, intellectual and psychiatric disabilities) reported by parents, teachers, or caregivers.

Instrument. We used the Test of Gross Motor Development - 3rd Edition (TGMD-3) [45] validated for Brazilian children [47] to assess children’s locomotor skills (LOCs: run, gallop, hop, skip, horizontal jump, slide) and ball skills (BS: two-hands strike, one-hand strike, stationary dribble, catch, kick, overhand throw, underhand throw) performance. Each skill has 3 to 5 performance criteria describing the efficient movement pattern. We assess the children using the TGMD-3 protocol recommendation. Following the TGMD-3 manual, we used the raw score for each subtest (LOC: 0 to 46; BS: 0 to 54) and the sum of the subtest to convert the scores in the Gross Motor Index (GMI) to obtain the categorization of motor delays (GMI scores < 70) and borderline impaired performance (GMI scores < 70 and 79) in the present study [45].
Procedures. The university ethics committee approved the study (CA 2008018). We contacted the board of education and school administrators from several cities in different states of Brazil; 22 schools in eight states responded positively to participation and agreed that we conducted the assessment in the school facilities. Researchers explained the purposes and procedures of the study in a meeting with the school administrator, staff, and teachers. We randomly selected children and parents within the school, or legal guardians were contacted and received all information about the research procedures. Writing consent was obtained from each child’s parents or custodial caregiver(s); each child verbally agreed to participate in the study. Trained professionals assessed the children consecutively, in pairs at schools. The assessments occur during one session of approximately 30 minutes. All tests were video recorded for later motor coding.

Data quality control followed a two-step process. First, two trained raters with extensive coding experience with the TGMD-3 test coded all video records (N = 1000). Then, 100 children were randomly selected for intra-rater and interrater reliability analysis. ANOVA-based intraclass correlations were conducted. Intra-rater (with two-month interval; ICC = from .70 to .90) and interrater (ICC = .85 to .99) reliability were high. Second, data entry errors and inconsistent records were identified and corrected. Data cleaning was performed in Microsoft Excel—360 and IBM SPSS, version 22.0 (SPSS Inc., Chicago, IL, US).

Data analysis. Shapiro Wilk test was used to verify the normality of data distribution according to each tested condition (e.g., boys and girls by age); the results showed normality of data distribution in all conditions (values between .963 and .071). Descriptive analyses (i.e., mean, standard deviation, absolute frequency, and percentage) were conducted. We used the One-Sample t-tests to compare the motor performance (LOCS and BS skills) of Brazilian children with the performance of the children from other countries’ samples, Ireland [2, 3]; Germany [43]; Finland [4, 44], and the US [45]. Cohen’s d analyses were provided as a measure of effect size. We conducted all analyses using Statistical Package for Social Science–SPSS, version 22 for Windows (SPSS Inc., Chicago, IL, US); we adopted the significance level at \( \alpha < 0.05 \).

Results

Motor delays and borderline impaired performance for Brazilian girls and boys

Table 1 provides the means (M) and standard deviations (SD) for the LOCS and BS and the prevalence of delays and borderline performance for Brazilian boys and girls by age. The prevalence of delays (girls: 28.3%; boys: 10.6%) and borderline impaired (girls: 27.5%; boys 22.7%) performances were high for girls and boys. Delays increased with age for boys and girls, and borderline performance increased for girls from 3 to 6 years old and remained around 20 percent until 10-years-old; whereas for the boys, it increased until the age of 7-years-old and then remained stable at around 30 percent.

Girls’ LOCS and BS motor trajectories across country comparisons

Fig 2A shows LOCS scores for Brazilian, Irish, Finnish, German, and American girls. The results showed that Brazilian girls compared to Irish study 1 girls [3] had lower LOCS scores at 6-years-old (t = -2.6, p = .012) and higher at 9-years-old (t = 3.4, p = .001). Regarding the other countries, Brazilian girls showed significant lower LOCS scores in all age groups (t values between -12.8 and -11.2; p values between .002 and < .001), except at 4-years-old German girls (t = 1.11, p = .267).

Fig 2B shows BS scores for Brazilian, Irish study 1, Irish study 2, Finnish study 1, Finnish study 2, and American girls. The results showed lower BS for Brazilian girls than the Irish
study 1 on 7-, 9-, and 10-years-old (t values between -3.57 and 2.57; p values between .001 and <.001). In addition, Brazilian girls showed lower BS than Irish study 2 in each age assessed (t values between -9.37 and -2.69; p values between <.001). Also, Brazilian girls showed lower BS than Finnish study 1 and American girls in each age assessed (t values between -16.45 and -2.22, p values between .032 and <.001). Exceptions were observed for Brazilian and Finnish girls (study 2) at 3- and 4-years-old and Brazilian and American girls at 4-years-old (t values between -.96 and .06, p values between .946 and .336). S1-S4 Tables in S1 File present all analysis results and are provided as supplementary material.

Table 2 provides the statistical results for the individual LOCS and BS comparisons across countries for girls. The results showed significantly higher scores for the Finnish girls than Brazilian girls for the run, hop, slide, jump, and two-hands strike from 3- to 10-years-old, with moderate to large effect size. Finnish girls also had higher scores on the gallop and one-hand

| Age  | GIRLS | BOYS |
|------|-------|------|
|     | N    | LOCS M (SD) | BS M (SD) | Delays N (%) | Borderline N (%) | N | LOCS M(SD) | BS M(SD) | Delays N(%) | Borderline N(%) |
| 3   | 28   | 13.7 (7.6) | 13.1 (4.3) | 1 (2.7) | 9 (24.3) | 20 | 13.5 (6.1) | 16.4 (4.6) | - | 3 (7.1) |
| 4   | 61   | 19.9 (7.3) | 18.3 (6.3) | - | 9 (18.8) | 54 | 19.2 (6.8) | 21.7 (7.0) | - | 2 (4) |
| 5   | 81   | 22.7 (5.9) | 19.2 (5.6) | 2 (2.9) | 23 (33.8) | 86 | 23.4 (6.6) | 24.6 (7.1) | 1 (1.4) | 6 (8.7) |
| 6   | 70   | 25.4 (7.2) | 22.0 (6.6) | 15 (22.4) | 29 (43.3) | 61 | 27.2 (5.7) | 30.2 (6.2) | 2 (2.5) | 11 (13.8) |
| 7   | 77   | 28.8 (6.6) | 27.2 (7.1) | 20 (27.0) | 21 (28.4) | 51 | 30.0 (7.2) | 33.5 (7.7) | 2 (3.4) | 22 (37.9) |
| 8   | 73   | 29.4 (6.7) | 30.0 (9.2) | 30 (42.9) | 15 (21.4) | 55 | 29.6 (6.7) | 36.2 (8.1) | 14 (19.4) | 22 (30.6) |
| 9   | 69   | 30.6 (6.2) | 31.3 (8.6) | 38 (51.4) | 17 (23.0) | 89 | 30.7 (6.4) | 36.8 (7.6) | 14 (17.9) | 31 (39.7) |
| 10  | 65   | 30.1 (5.6) | 29.9 (7.0) | 35 (58.3) | 14 (23.3) | 60 | 31.4 (5.3) | 36.1 (7.8) | 20 (37.7) | 17 (32.1) |
| Total | 524 | 24.7 (8.6) | 24.5 (9.8) | 141 (28.3) | 137 (27.5) | 476 | 25.0 (8.6) | 28.2 (9.0) | 53 (10.6) | 114 (22.7) |

Note: M: mean; SD: standard deviation; LOCS: Locomotor skills; BS: Ball skills; GMQ: Gross motor quotient; Raw score range: LOCS = 0 to 46, BS = 0 to 54; Motor delays (GMI scores < 70) and borderline impaired (GMI scores < 70 and 79) (Ulrich, 2019).

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Fig 2. Motor trajectory for LOCS (2a) and BS (2b) for girls across countries.

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strike, with small to large effect sizes, in different age groups. Brazilian girls showed higher scores than Finnish girls on catch from 3- to 5-years-old, with moderate to large effect sizes, and kick from 3- to 9-years-old, with moderate to large effect sizes. For skip, Brazilian girls at 3- and 6-years-old showed higher scores, whereas 4- and 7- to 10-years-old Finnish girls had higher scores than the other groups; small to moderate effect sizes were found. A similar trend was found for dribble, at 5-years-old Brazilian girls had higher scores, whereas from 6- to 10-years-old, Finnish girls had higher scores than Brazilians.

The analyses also showed higher scores for the Irish girls than Brazilian girls for jump and underhand throw and overhand throw from 6- to 10-years-old, with moderate to very large effect size. Irish girls also had higher scores on the hop, slide, one-hand strike, and dribble, with moderate effect sizes, in different age groups. Brazilian girls showed higher scores than Irish girls on the catch from 6- to 10-years-old and on the run, gallop, two-hands strike, and kick with large and very large effect sizes in some age groups.

Figs 3 and 4 provided the individual LOCS and BS trajectories for girls across countries. The development trajectory for the girls seems to achieve its peak around the age of 8- and 9-years-old for LOC and BS subtests, respectively. For all the samples, tiny increments were observed after that period, the only exception was the American girls on BS—increments were observed until 10-years-old, the ceiling effect was not observed in the samples. Regarding individual skills, no increments were observed after 8-years-old for any LOC skills; for the BS—two-hands strike with and overhand throw, some increments were observed from 8- to 10-years-old Finland girls.

Table 2. Comparisons across WEIRD countries and Brazil: Statistical results (p and Cohen’s d) for the individual LOCS and BS for girls.

| SKILLS       | GIRLS: BR¹ x FI² | Non-sig p > .050 | GIRLS: BR¹ x IRI³ | Non-sig p > .050 |
|--------------|------------------|-----------------|------------------|-----------------|
| Age (years)  | P         | d       | Age (years)  | P         | d       | Age (years)  | P         | d       |
| Run          | 3–10      | < .001¹  | .76 to 1.5 | 6–7 & 9–10 | < .001¹  | .66 to 1.5 | 8       |
| Gallop       | 3 & 6–8   | < .003¹  | .36 to .61 | 4–5 & 9–10 | 9       | < .001¹  | .04       | 6–8 &10 |
| Hop          | 3–10      | < .001¹  | .67 to 1.9 | 6       | .003¹   | .37       | 7–10    |
| Skip         | 3 & 6     | ≤ .023¹  | .36 & .29 | 5       | -       | -         | 6–10    |
|              | 4 & 7–10  | ≤ .046¹  | .29 to .67 |         |         |           |         |
| Slide        | 3–10      | < .001¹  | .53 to .98 | 6 & 7   | .001¹   | .52 & .25 | 8–10    |
| Jump         | 3–10      | < .046¹  | .32 to 1.3 | 6–10   | < .001¹ | .44 to 1.1 |         |
| Strike 2-hands | 3–10     | < .001¹  | .40 to 1.5 | 6–8    | < .001¹ | .47 to .72 | 9–10    |
| Strike 1-hand | 4–10     | ≤ .001¹  | .47 to .89 | 3       | 6–7 & 9–10 | ≤ .003¹ | .48 to .51 | 8       |
| Dribble      | 5         | < .001¹  | .41       | 3–4    | 6 & 9–10 | < .001¹ | .54 to .75 | 7–8     |
|              | 6–10      | ≤ .009¹  | .34 to .70 |         |         |           |         |
| Catch        | 3–5       | < .001¹  | .41 to .81 | 6 & 8–10 | 6–10   | ≤ .002¹  | .39 to 1.4 |         |
|              | 7         | < .001¹  | .07       |         |         |           |         |
| Kick         | 3–9       | ≤ .009¹  | .40 to .83 | 10      | 6–9    | < .001¹  | .79 to 1.0 | 10      |
| Underhand throw | 4–10     | < .001¹  | .40 to 1.6 | 3       | 6–10   | < .001¹  | .91 to 1.5 |         |
| Overhand throw | 3 & 5–10 | < .001¹  | .27 to 1.3 | 4       | 6–10   | ≤ .019¹  | .36 to .65 |         |

Note: ¹ Present study; ² Rintala et al. [44], 2016; ³ Kelly et al., 2018 [3]; Higher scores for: BR Brazilian girls; FI Finland girls; IRI Irish girls.
Boys LOCS and BS motor trajectories across country comparisons

Fig 5A shows the LOCS scores for Brazilian, Irish, Finnish (studies 1 and 2), German, and American boys. Compared to Irish, Brazilian boys showed lower LOCS scores at 8-years-old ($t = -2.57$, $p = .012$) and higher at 9 and 10-years-old ($t$ values -3.41 and -3.67, $p$ values = .001). Brazilian boys showed lower LOCS performance compared to German, Finnish (study 1), Finnish (study 2) and American ($t$ values between -9.57 and -12.66, $p$ values between .005 and <.001) in each age assessed; except at 3-years-old between Brazilian and American ($t = -1.41$, $p = .167$) and Brazilian and Finnish (study 2) ($t = -1.46$, $p = .153$). S1-S4 Tables in S1 File present all analysis results and are provided as supplementary material.

Fig 5B shows BS scores for Brazilian, Irish (studies 1 and 2), Finnish (studies 1 and 2), and American boys. Brazilian boys showed lower BS than Irish (study 1) in each age assessed ($t$ values between -5.32 and -2.60; $p$ values between .002 and <.001). Brazilian boys also showed lower BS than Irish (study 2) boys at 5, 9 and 10-years-old ($t$ values between -6.05 and -3.05; $p$ values <.001). In addition, Brazilian boys also showed lower BS compared to Finnish (studies 1 and 2) and Americans in each assessed age ($t$ values between -2.64 and -12.25; $p$ values between .021 and <.001), except at 3- and 4-years-old between Brazilian and Finnish (study 2), and at 3-years-old, between Brazilian and Americans ($t$ values between -.81 and -.04; $p$ values between .964 and .442).

Table 3 provides the statistical test results for the individual LOCS and BS comparisons across countries for boys. In all age groups, the analyses showed significantly higher scores for the Finnish than Brazilian boys for the run, hop, jump, one-hand strike, two-hands strike, and the underhand throw, with moderate to very large effect size. Finnish boys also had higher gallop, slide, dribble, and overhand throw scores in different age groups, with small to large effect sizes. Brazilian boys showed a higher score than Finnish boys on the skip from 4- to 5-years and 10-years-old, dribble at the 4-years-old, catch from 3- to 5-years-old, and kick from 3- to 6-years old, with small to moderate effect sizes.
The analyses also showed significantly higher scores for the Irish boys than Brazilian boys for jump, one-hand strike, dribble, and underhand throw and overhand throw from 6- to 10-years-old, with moderate to large effect size. Irish boys also had higher gallop, hop, slide, and two-hands strike scores in some age groups, with moderate to large effect sizes. Brazilian boys showed higher scores than Irish boys on the run and catch at most age groups, and on the skip in some age groups, with small to moderate effect sizes. Regarding the kick, Brazilian boys showed higher scores than Irish boys on the run and catch at most age groups, and on the skip in some age groups, with small to moderate effect sizes. Regarding the kick, Brazilian boys showed higher scores at 6-years-old whereas the Irish boys at 8-years-old.

Figs 6 and 7 provided the individual LOCS and BS trajectories for boys across countries. Overall, the development trajectory for the boys achieves its peak around 9- and 10-years-old for LOC and BS subtests, respectively. More variation was observed for LOCS; the samples did not show the ceiling effect. Some increments were observed for the skip from 8- to 10-years-old for Brazilian and Irish boys. For the one-hand strike and two-hands strike, and underhand throw, some increments were observed from 9- to 10-years-old for Finnish boys.

Please refer to S1-S4 Tables in S1 File for all statistical results.
Discussion

This study aimed to examine the prevalence of delays and borderline impaired performance for girls and boys in an LMIC country—Brazil, the variation in the motor trajectories.

Table 3. Comparisons across WEIRD countries and Brazil: Statistical results (p and Cohen’s d) for the individual LOCS and BS for boys.

| SKILLS | BOYS: BR x FI | BOYS: BR x IRI |
|--------|---------------|----------------|
|        | Age (years)   | P            | d   | Age (years) | P            | d   | Age (years) | P            | d   |
| Run    | 3–10          | ≤ .023<sup>1</sup> | .31 to 1.2 | -     | 6–10          | <.001<sup>BR</sup> | .54 to 1.0 | -     |
| Gallop | 3 & 8         | ≤ .002<sup>1</sup> | .51 & .52 | 4–7 & 9–10 | 8             | <.001<sup>IRI</sup> | .48 | 6–7 & 10   | -     |
| Hop    | 3–10          | <.001<sup>1</sup> | .56 to 1.3 | -     | 6, 8 & 10     | <.023<sup>IRI</sup> | .18 to .53 | 7 & 9 | -     |
| Skip   | 4–5 & 10      | ≤ .043<sup>BR</sup> | .25 to 45 | 3, 6–7 & 9–10 | 9–10       | ≤ .038<sup>IRI</sup> | .26 & .41 | 6–8 | -     |
|        | 8             | .002<sup>1</sup> | .38 | -     | -             | -             | -     | -     | -     |
| Slide  | 3 & 5–10      | ≤ .048<sup>1</sup> | .25 to .80 | 4     | 6–9           | ≤ .002<sup>IRI</sup> | .42 & .75 | 10 | -     |
| Jump   | 3–10          | <.001<sup>1</sup> | .60 to 1.6 | -     | 6–10          | ≤ .003<sup>IRI</sup> | .44 to .91 | -     | -     |
| Strike 2-hands | 3–10       | <.001<sup>1</sup> | .88 to 1.5 | -     | 9–10          | ≤ .026<sup>IRI</sup> | .31 to .81 | 6–8 | -     |
| Strike 1-hand | 3–10         | ≤ .003<sup>1</sup> | .34 to .19 | -     | 6–10          | <.001<sup>IRI</sup> | .67 to .97 | -     | -     |
| Dribble | 6–10          | ≤ .007<sup>IRI</sup> | .39 to 1.2 | 3 & 5 | 6–10          | ≤ .026<sup>IRI</sup> | .31 to .81 | -     | -     |
|        | 4             | .018<sup>BR</sup> | .02 | -     | -             | -             | -     | -     | -     |
| Catch  | 3–5           | <.001<sup>1</sup> | .38 to 1.4 | 6–10 | 6–10          | ≤ .046<sup>IRI</sup> | .24 to 1.1 | -     | -     |
| Kick   | 3–6           | ≤ .016<sup>BR</sup> | .59 to .94 | 7–8 & 10 | 6             | <.006<sup>BR</sup> | .40 | 7 & 9–10   | -     |
|        | 9             | <.023<sup>1</sup> | .28 | 8     | <.001<sup>IRI</sup> | .31 | -     | -     |
| Underhand throw | 3–10        | <.001<sup>1</sup> | .82 to .19 | -     | 6–10          | <.001<sup>IRI</sup> | .75 to 1.4 | -     | -     |
| Overhand throw | 3–4 & 6–10  | ≤ .016<sup>1</sup> | .38 to 1.2 | 5     | 6–10          | <.001<sup>IRI</sup> | .69 to .95 | -     | -     |

Note: 1 Present study; 2 Rintala et al. [44], 2016; 3 Kelly et al., 2018 [3]; Higher scores for: BR Brazilian boys, FI Finland boys, IRI Irish boys.

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(locomotor and ball skills) of girls and boys (3- to 10-years-old) across WEIRD countries, and Brazil, as well as the differences in the trajectories of specific skills for girls and boys across the countries. The evidence showed that Brazilian girls and boys had overall lower scores on the LOCS and BS subtest compared to Finnish, Irish, German, and American girls, as well as lower scores in most of the individual skills, compared to Finnish [44] and Irish [3] children, the only two samples that provided data for individual skills.

Overall, lower motor scores were observed for Brazilian girls and boys than the children in the WEIRD countries. Like previous Brazilian studies, the results indicated a higher prevalence of lower motor scores for Brazilian children across sex, age [5, 15, 19, 26], and socioeconomic status [31, 33, 37]. Children living in vulnerability had less opportunity to develop motor skills. It is essential to notice that SES is a crucial factor affecting children worldwide. Poverty has a striking influence on children due to the cumulative and prolonged exposure to risk factors, limiting the conditions for appropriate stimulation and access to opportunities that favor development outcomes at home and schools [33, 48–52]. Consequently, poverty underlays the other risk factors for adverse opportunities provided for children in Brazil and the consequent developmental outcomes [37, 53], and it may be the plausible explanation for the present result since 60% of children were from low-income families.

Regarding cross-cultural differences, the motor trajectories were distinct for the WEIRD countries compared to Brazil; overall, higher scores for LOCS and BS were observed for Americans, Finish, German, and Irish children than Brazilians. However, there were also exceptions; Brazilian children had a higher skip, catch, and kick scores than Finnish and Irish children. Compared to Finnish children, the advances for Brazilians were more prevalent up to 6-years-old, except for kick for girls—the higher scores found for Brazilian girls were from 3- to 9-years-old. Concerning Brazilian and Irish comparisons, the analysis was restricted to 6- to 10-years-old (the Irish study did not assess younger children), the Brazilian advances were
observed from 6- to 10-years-old for most skills, the exception was the kick for boys that the advance for Brazilian’s boys was restricted to the age of 6-years-old.

Brazilian children’s experiences across childhood with dance, dodge games, and soccer practices at home and school may explain our results. Motor proficiency is supported by the exposure of the child to the family leisure activities at home [54], the home opportunities provided for the child [29, 55–57], the landscape in which the child play [55, 57, 58], the school curriculum [14, 59, 60], and the opportunities to engage in sports practices [14]. Our results support these contentions.

Among the after-school activities reported by the children in Brazil, soccer, and dance, respectively first and second, are the more frequent activities reported [14, 55, 57, 61]. The skip consists of a step and a hop, and its variants are part of several dance styles such as street, modern, ballet, and jazz. Kick is the focus of soccer, and soccer is the national sport in Brazil, played by children on every possible makeshift field [62], although it is still more prevalent among boys [14, 63]. Besides, dodge ball, known as "queimada" in Brazil, is a popular game and part of Brazil’s physical education curriculum [64]. The dodge game requires that the child catch a ball with different velocity, direction, and dislocation demands–features of proficient catching.
The means and variances for LOC and BS indicated a tendency, across all countries, for stabilization in scores at the age of 8- and 9-years-old for girls, whereas for boys at 9- and 10-years-old. No ceiling effects were found. The girls’ high means for LOCs were 7 points (American girls) to 16 points (Brazilian and Irish girls) below the maximum score in the test; and, for BS, 8 points (American girls) to 24 points (Brazilian girls). A similar trend was observed for boys; the boys’ high means for LOCs were 7 points (American and Finish boys) to 16 points (Irish boys) below the maximum score; and, for BS, 5 points (American and Finish boys) to 18 points (Brazilian boys). Although motor performance differences prevailed among the investigated samples, moments of similar motor performances were across countries, more prevalent in the youngest ages (3- to 6-years-old). The low means and lack of ceiling effects lead us to inquire why children acquire several motor criteria for each skill but lack to acquire the more proficient ones. Further investigation is necessary to understand how children are being demanded to be more skilled within the context. In addition, if less instruction and feedback are provided to children after they acquire the essential motor criteria for a specific skill and become more independent to use the skill during games.

Another relevant aspect of this study was the observation of periods of stability in motor skill acquisitions, specifically after 8-years-old. This stability and instability in motor skill acquisition highlight the importance of monitoring the child’s motor trajectory to identify the actual motor changes and the periods of the crucial need for the teacher intervention to breach the proficiency barriers. However, the lack of individual skills means for several countries (US and Germany) limited, in part, the comparison of population samples and the discussion regarding the peculiarities of each skill. Besides, caution is necessary for interpreting these results since it is a cross-sectional design.

Strengths and limitations

The strength of this study was to compare motor outcomes of girls and boys across diverse cultural contexts, WEIRD and LMIC countries, and provided evidence that children in LMIC(s) need further attention due to the lower scores in the motor trajectory across childhood. We also provided evidence that the cultural motor practices in Brazil (e.g., dance, soccer, dodge ball games) probably affect children’s performance since the only skills that Brazilian girls and boys showed consistently higher scores were skipped, kicking, and catching.

The results also highlight the need for further research to assess the exposure to different risk factors, biological (e.g., prematurity, exposure to drugs and heavy metals) and social (e.g., accesses to enrichment programs, leisure time, daily routine), or even different levels of risks between LMIC and WEIRD countries, and how it affects motor performances. Culture, family beliefs, curriculum, and opportunities to practice motor skills differ from LMIC and WEIRD countries; these factors also need further investigation—a limitation in the present study. Nevertheless, SES plays a relevant role in children’s opportunities to learn and acquire skills [36]. Although it was assessed in the Brazilian sample (60% of the children were from middle-low and poor), we have no information regarding families’ SES for the WEIRD countries’ studies, limiting our capability to analyze those differences further. Another limitation is the cross-sectional design; longitudinal data wild provided exciting insights into individual variations.

Conclusion

In this cross-sectional study, the observed difference in gross motor trajectories for LOCs and BS of Brazilian children compared to WEIRD countries may have been determined by risk factors that increase vulnerability and predisposition to overall impairments from children from LMIC(s). Children from LMIC endure more health, nutrition, and social factors that prevent
them from reaching their developmental potential; all aspects are emphasized by poverty. This exposure may have negative repercussions on the acquisition of motor skills.

This study is grounded in the understanding that countries’ differences or similarities in children’s performance and specific details about the actual differences across skills and age could lead to a collective effort to better understand motor trajectories across childhood in the light of each country’s singularities. A relevant part of the study was that engaging in critical inquiry about the Brazilian results compared to other countries could be a continuous learning process and possibly change the curriculum practices and improve children’s learning opportunities. Our results provided evidence that children from Brazil may need more extensive and cohesive support from schools and families and effective public policies to improve their motor competence. Here, we chose to point out the potential of a cross-cultural claim to challenge the status quo of children’s competence with international guidelines to develop motor skills across different cultures.

Supporting information

S1 File. Contains all the supporting tables.

(DOCX)

Author Contributions

Conceptualization: Nadia Cristina Valentini, Glauber Carvalho Nobre, Marcelo Gonçalves Duarte.

Data curation: Nadia Cristina Valentini, Glauber Carvalho Nobre, Marcelo Gonçalves Duarte.

Formal analysis: Nadia Cristina Valentini, Glauber Carvalho Nobre, Marcelo Gonçalves Duarte.

Investigation: Nadia Cristina Valentini.

Methodology: Nadia Cristina Valentini, Glauber Carvalho Nobre, Marcelo Gonçalves Duarte.

Supervision: Nadia Cristina Valentini.

Validation: Nadia Cristina Valentini.

Visualization: Nadia Cristina Valentini.

Writing – original draft: Nadia Cristina Valentini, Glauber Carvalho Nobre, Marcelo Gonçalves Duarte.

Writing – review & editing: Nadia Cristina Valentini, Glauber Carvalho Nobre.

References

1. Barnett LM, Lai SK, Veldman SLC, Hardy LL, Cliff DP, Morgan PJ, et al. Correlates of Gross Motor Competence in Children and Adolescents: A Systematic Review and Meta-Analysis. Sport Med [Internet]. 2016 Nov 19; 46(11):1663–88. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26894274 https://doi.org/10.1007/s40279-016-0495-z

2. Behan S, Belton S, Peers C, O’Connor NE, 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 [Internet]. 2019 May; 37(22):2604–12. Available from: https://doi.org/10.1080/02640414.2019.1651144 PMID: 31379260

3. Kelly L, O’Connor S, Harrison AJ, Ní Chéilleachair NJ. Does fundamental movement skill proficiency vary by sex, class group or weight status? Evidence from an Irish primary school setting. J Sports Sci
Gross motor skills: A cross-cultural study

4. Niemistö D, Finni T, Haapala E, Cantell M, Korhonen E, Sääkslahti A. Environmental Correlates of Motor Competence in Children—The Skilled Kids Study. Int J Environ Res Public Health [Internet]. 2019 Jun 4; 16(11):1989. Available from: https://www.mdpi.com/1660-4601/16/11/1989 https://doi.org/10.3390/ijerph16111989 PMID: 31167487

5. Valentini NC, Logan SW, Spessatto BC, de Souza MS, Pereira KG, Rudisill ME. Fundamental Motor Skills Across Childhood: Age, Sex, and Competence Outcomes of Brazilian Children. J Mot Learn Dev [Internet]. 2016 Jun; 4(1):16–36. Available from: https://journals.humankinetics.com/view/journals/jmld/4/1/article-p16.xml

6. Bardid F, Lenoir M, Huyben F, De Martelaer K, Seghers J, Goodway JD, et al. The effectiveness of a community-based fundamental motor skill intervention in children aged 3–8 years: Results of the "Multi-move for Kids" project. J Sci Med Sport [Internet]. 2017 Feb; 20(2):184–9. Available from: https://doi.org/10.1016/j.jsams.2016.07.005 PMID: 27639417

7. Brauner L, Valentini NC, Souza MS de, Zanella LW, Berleze A. A influência de um programa de iniciación esportiva no desempenho motor e na rotina de atividades de crianças. Rev Bras Educ Física e Esporte. 2019 Mar; 33(4):569–86.

8. D'Hondt E, Venetsanou F, Kambas A, Lenoir M. Motor Competence Levels in Young Children: A Cross-Cultural Comparison Between Belgium and Greece. J Mot Learn Dev [Internet]. 2019 Dec; 7(3):289–306. Available from: https://journals.humankinetics.com/view/journals/jmld/7/3/article-p289.xml

9. Gonçalves GS, Cardozo PL, Valentini NC, Chviacovsky S. Enhancing performance expectancies through positive comparative feedback facilitates the learning of basketball free throw in children. Psychol Sport Exerc [Internet]. 2018 May; 36(5):174–7. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1469029217307185

10. Valentini NC, Pierosan L, Rudisill ME, Hastie PA. Mastery and exercise play interventions: motor skill development and verbal recall of children with and without disabilities. Phys Educ Sport Pedagog [Internet]. 2017 Jul; 22(4):349–63. Available from: https://www.tandfonline.com/doi/full/10.1080/17408989.2016.1241223

11. Barnett LM, Hnatuk JA, Salmon J, Hesketh KD. Modifiable factors which predict children’s gross motor competence: a prospective cohort study. Int J Behav Nutr Phys Act [Internet]. 2019 Dec 11; 16(1):129. Available from: https://ijbnpa.biomedcentral.com/articles/10.1186/s12966-019-0888-0 PMID: 31829267

12. Valentini NC, de Almeida CS, Smith BA. Effectiveness of a home-based early cognitive-motor intervention provided in daycare, home care, and foster care settings: Changes in motor development and context affordances. Early Hum Dev [Internet]. 2020 Dec; 151(1):105223. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0378378220303480

13. Dania A, Kaïoglou V, Venetsanou F. Validation of the Canadian Assessment of Physical Literacy for Greek children: understanding assessment in response to culture and pedagogy. Eur Phys Educ Rev. 2020 Jun; 26(4):903–19.

14. Nobre FSS, Valentini NC, Rudisill ME. Applying the biomecological theory to the study of fundamental motor skills. Phys Educ Sport Pedagog [Internet]. 2020 Jan 2; 25(1):29–48. Available from: https://www.tandfonline.com/doi/full/10.1080/17408989.2019.1688772

15. Saccani R, Valentini NC. Cross-cultural analysis of the motor development of Brazilian, Greek and Canadian infants assessed with the Alberta Infant Motor Scale. Rev Paul Pediatr [Internet]. 2013 Sep; 31(3):350–8. Available from: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-05822013000300350&lng=en&tlng=en https://doi.org/10.1590/S0103-05822013000300012 PMID: 24142318

16. Brian A, Taunton S. Effectiveness of motor skill intervention varies based on implementation strategy. Phys Educ Sport Pedagog [Internet]. 2018 Jun; 23(2):222–33. Available from: https://doi.org/10.1080/17408989.2017.1413709

17. Tomaz SA, Jones RA, Hinkelty T, Bernstein SL, Twine R, Kahn K, et al. Gross motor skills of South African preschool-aged children across different income settings. J Sci Med Sport [Internet]. 2019 Jun; 22 (6):689–94. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1440244018309137 https://doi.org/10.1016/j.jsams.2018.12.009 PMID: 30606626

18. Brian A, Pennell A, Taunton S, Starrett A, Howard-Shaughnessy C, Goodway JD, et al. Motor Competence Levels and Developmental Delay in Early Childhood: A Multicenter Cross-Sectional Study Conducted in the USA. Sport Med [Internet]. 2019 Jun; 49(10):1609–18. Available from: https://doi.org/10.1007/s40279-019-01150-5

19. Valentini NC, Getchell N, Logan SW, Liang L-Y, Golden D, Rudisill ME, et al. Exploring Associations between Motor Skill Assessments in Children With, Without, and At-Risk for Developmental
Gross motor skills: A cross-cultural study

19. Bardid F, Rudd JR, Lenoir M, Polman R, Barnett LM. Cross-cultural comparison of motor competence in children from Australia and Belgium. Front Psychol [Internet]. 2015; 6(July):964. Available from: https://journal.frontiersin.org/article/10.3389/fpsyg.2015.00964

20. Bardid F, Huyben F, Lenoir M, Seghers J, De Martelaber K, Goodway JD, et al. Assessing fundamental motor skills in Belgian children aged 3–8 years highlights differences to US reference sample. Acta Paediatr Int J Paediatr. 2016 Apr; 105(6):e281–90. https://doi.org/10.1111/ajpa.13380

21. Luz C, Cordovil R, Rodrigues LP, Gao Z, Goodway JD, Sacko RS, et al. Motor competence and health-related fitness in children: A cross-cultural comparison between Portugal and the United States. J Sport Heal Sci. 2019; 8(2):130–6. https://doi.org/10.1016/j.js.hs.2019.01.005

22. Haga M, Tortella P, Aronsitou K, Charitou S, Koutsouki D, Fumagalli G, et al. Cross-Cultural Aspects: Exploring Motor Competence Among 7- to 8-Year-Old Children From Greece, Italy, and Norway. SAGE Open [Internet]. 2018 Apr 3; 8(2):1–9. Available from: http://journals.sagepub.com/doi/10.1177/2158244018768381

23. Spessato BC, Gabbard C, Valentini N, Rudisill M. Gender differences in Brazilian children’s fundamental movement skill performance. Early Child Dev Care [Internet]. 2013 Jul; 183(7):916–23. Available from: http://www.tandfonline.com/doi/abs/10.1080/03004430.2012.689761

24. Lopes VB, de Lima CD, Tuddella E. Motor acquisition rate in Brazilian infants. Infant Child Dev [Internet]. 2009 Mar; 18(2):122–32. Available from: https://onlinelibrary.wiley.com/doi/10.1002/icd.595

25. Cromwell EA, Dube Q, Cole SR, Chirambo C, Dow AE, Heyderman RS, et al. Validity of US norms for the Bayley Scales of Infant Development-III in Malawian children. Eur J Paediatr Neurol [Internet]. 2014 Dec; 18(2):223–30. Available from: https://doi.org/10.1016/j.ejpn.2013.11.011

26. Sales Nobre FS, Ribeiro Bandeira PF, Valentini NC. Atrases motores em crianças desfavorecidas socioeconomicamente. Um olhar Bioecologico. Motricidade [Internet]. 2016 Oct; 12(2):59. Available from: http://revistas.rcaap.pt/motricidade/article/view/7178

27. Sales Nobre FS, Ribeiro Bandeira PF, Valentini NC. Motor competence of schoolchildren from public education in São Paulo city, Brazil. J Phys Educ. 2018 Jul; 29(1):1–8.

28. Nobre GC, Valentini NC, Nobre FSS. Motor and school performance, self-perception of competence and nutritional status of children across ages: The role of social vulnerability on child development. J Phys Educ Sport. 2018 Nov; 18(3):1478–87.

29. Nobre GC, Valentini NC, Nobre FSS. Fundamental motor skills, nutritional status, perceived competence, and school performance of Brazilian children in social vulnerability: Gender comparison. Child Abuse Negl [Internet]. 2018 Jun; 80:335–45. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1980657418301583

30. Coordinating Disorder. J Mot Learn Dev [Internet]. 2015 Jun; 3(1):39–52. Available from: https://journals.humankinetics.com/view/journals/mld/3/1/article-p39.xml

31. Coordinating Disorder. J Mot Learn Dev [Internet]. 2015 Jun; 3(1):39–52. Available from: https://journals.humankinetics.com/view/journals/mld/3/1/article-p39.xml

32. Coordinating Disorder. J Mot Learn Dev [Internet]. 2015 Jun; 3(1):39–52. Available from: https://journals.humankinetics.com/view/journals/mld/3/1/article-p39.xml

33. Coordinating Disorder. J Mot Learn Dev [Internet]. 2015 Jun; 3(1):39–52. Available from: https://journals.humankinetics.com/view/journals/mld/3/1/article-p39.xml

34. Coordinating Disorder. J Mot Learn Dev [Internet]. 2015 Jun; 3(1):39–52. Available from: https://journals.humankinetics.com/view/journals/mld/3/1/article-p39.xml

35. Coordinating Disorder. J Mot Learn Dev [Internet]. 2015 Jun; 3(1):39–52. Available from: https://journals.humankinetics.com/view/journals/mld/3/1/article-p39.xml

36. Coordinating Disorder. J Mot Learn Dev [Internet]. 2015 Jun; 3(1):39–52. Available from: https://journals.humankinetics.com/view/journals/mld/3/1/article-p39.xml

37. Coordinating Disorder. J Mot Learn Dev [Internet]. 2015 Jun; 3(1):39–52. Available from: https://journals.humankinetics.com/view/journals/mld/3/1/article-p39.xml
38. Pereira KR, Valentini NC, Saccani R. Brazilian infant motor and cognitive development: Longitudinal influence of risk factors. Pediatr Int [Internet]. 2016 Dec; 58(12):1297–306. Available from: https://onlinelibrary.wiley.com/doi/10.1111/ped.13021 PMID: 27084989
39. International Tennis Federation. Global tennis report [Internet]. 2021 [cited 2022 Feb 19]. p. 248. Available from: http://ift.uberflip.com/i/1401406-ift-global-tennis-report-2021/0?
40. Cortela CC, Ginciene G, Milisted M, de Souza SP, Abaide Balbinotti CA. Challenges for grassroots tennis development in Brazil. Coach Sport Sci Rev [Internet]. 2019 Jan; 1(77):21–2. Available from: https://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=136605013&lang=pt-br&site=ehost-live
41. Adolph KE, Robinson SR. Motor Development. In: Handbook of Child Psychology and Developmental Science [Internet]. Hoboken, NJ, USA: John Wiley & Sons, Inc.; 2015. p. 1–45. Available from: https://onlinelibrary.wiley.com/doi/10.1002/9781118963418.childpsy204
42. Moher D, Shamseer L, Clarke M, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev [Internet]. 2015 Dec 1; 4(1):1. Available from: https://systematicreviewsjournal.biomedcentral.com/articles/10.1186/2046-4053-4-1 https://doi.org/10.1186/2046-4053-4-1 PMID: 25554246
43. Wagner MO, Webster EK, Ulrich DA. Psychometric Properties of the Test of Gross Motor Development, Third Edition (German Translation): Results of a Pilot Study. J Mot Learn Dev [Internet]. 2017 Jun; 5(1):29–44. Available from: https://journals.humankinetics.com/view/journals/jmld/5/1/article-p29.xml
44. Rintala P, Sääkslahti A, Iivonen S. Basic motor skills for children aged 3 to 10. Liik ja T. 2016; 56(6):49–55.
45. Ulrich DA. Test of Gross Motor Development—third edition: Examiner’s manual. 3rd ed. Austin: PRO-ED; 2019. 100 p.
46. Instituto Brasileiro de Geografia e Estatística. Informações sobre os municípios brasileiros [Internet]. Brasília; 2014. Available from: http://www.cidades.ibge.gov.br/xtras/perfil.php?lang=&codmun=130340&search=amazonas7Cparintins7Cinfograficos:-informacoes-completas
47. Valentini NC, Zanella LW, Webster EK. Test of Gross Motor Development—Third Edition: Establishing Content and Construct Validity for Brazilian Children. J Mot Learn Dev [Internet]. 2017 Jun; 5(1):15–28. Available from: https://journals.humankinetics.com/view/journals/jmld/5/1/article-p15.xml
48. Evans GW, Fuller-Rowell TE. Childhood poverty, chronic stress, and young adult working memory: the protective role of self-regulatory capacity. Dev Sci [Internet]. 2013 Sep; 16(5):688–96. Available from: https://onlinelibrary.wiley.com/doi/10.1111/desc.12082 PMID: 24033574
49. Forns J, Julvez J, García-Esteban R, Guxens M, Ferrer M, Grellier J, et al. Maternal intelligence-mental health and child neuropsychological development at age 14 months. Gac Sanit [Internet]. 2012 Sep; 26(5):397–404. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0213911112000027 https://doi.org/10.1016/j.gaceta.2011.10.011 PMID: 22284911
50. Lipina SJ, Segretin MS. Strengths and weakness of neuroscientific investigations of childhood poverty: future directions. Front Hum Neurosci [Internet]. 2015 Feb 11;9(53):1–11. Available from: http://journal.frontiersin.org/Article/10.3389/fnhum.2015.00053/abstract https://doi.org/10.3389/fnhum.2015.00053 PMID: 25717299
51. Noble KG, Farah MJ. Neurocognitive consequences of socioeconomic disparities: the intersection of cognitive neuroscience and public health. Dev Sci [Internet]. 2013 Sep; 16(5):639–40. Available from: https://onlinelibrary.wiley.com/doi/10.1111/desc.12076 PMID: 24033569
52. Tomalski P, Moore DG, Ribeiro H, Axellson EL, Murphy E, Karmiloff-Smith A, et al. Socioeconomic status and functional brain development—associations in early infancy. Dev Sci [Internet]. 2013 Sep; 16(5):676–87. Available from: https://onlinelibrary.wiley.com/doi/10.1111/desc.12079 PMID: 24033573
53. Walker SP, Wachs TD, Meeks Gardner J, Lozoff B, Wasserman GA, Pollitt E, et al. Child development: risk factors for adverse outcomes in developing countries. Lancet [Internet]. 2007 Jan; 369(9556):145–57. Available from: https://linkinghub.elsevier.com/retrieve/pii/S014067360600762 https://doi.org/10.1016/S0140-6736(07)60076-2 PMID: 17223478
54. Suggate S, Stoeger H, Pufke E. Relations between playing activities and fine motor development. Early Child Dev Care [Internet]. 2017 Aug 3; 187(8):1297–310. Available from: https://www.tandfonline.com/doi/full/10.1080/03004430.2016.1167047
55. Berleze A, Valentini N. Intervention for Children with Obesity and Overweight and Motor Delays from Low-Income Families: Fostering Engagement, Motor Development, Self-Perceptions, and Playtime. Int J Environ Res Public Health. 2022 Jan; 19(5):2445.
56. Ferreira L, Godinez I, Gabbar E, Vieira JLL, Caçola P. Motor development in school-age children is associated with the home environment including socioeconomic status. Child Care Health Dev [Internet]. 2018 Nov; 44(6):801–6. Available from: https://onlinelibrary.wiley.com/doi/10.1111/cch.12606 PMID: 30066336
57. Berleze A, Valentini NC. The Motor intervention effectiveness on children daily routine, motor, health, and psychosocial parameters. J Phys Educ [Internet]. 2021 Out; 32(e3272):1–21. Available from: https://periodicos.uem.br/ojs/index.php/RevEduFis/article/view/55974

58. Fjertoft I, Sageie J. Landscape as Playscape: The Effects of Natural Environments on Children’s Play and Motor Development. Child Youth Environ [Internet]. 2000 Apr; 48(1–2):83–97. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0169204600000451

59. Duncan MJ, Roscoe CM, Noon M, Clark CC, O’Brien W, Eyre EL. Run, jump, throw and catch: How proficient are children attending English schools at the fundamental motor skills identified as key within the school curriculum? Eur Phys Educ Rev [Internet]. 2020 Nov 23; 26(4):814–26. Available from: http://journals.sagepub.com/doi/10.1177/1356336X19888953

60. Mukherjee S, Ting Jamie LC, Fong LH. Fundamental Motor Skill Proficiency of 6- to 9-Year-Old Singaporean Children. Percept Mot Skills [Internet]. 2017 Jun 4; 124(3):584–600. Available from: http://journals.sagepub.com/doi/10.1177/0031512517703005 PMID: 28376671

61. Andrade Neto F, Eto FN, Pereira TSS, Carletti L, Molina MDCB. Active and sedentary behaviours in children aged 7 to 10 years old: the urban and rural contexts, Brazil. BMC Public Health [Internet]. 2014 Dec 18; 14(1):1174. Available from: http://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-14-1174

62. Garcia-Navarro L. For Brazil’s soccer stars, careers often begin on makeshift fields. [Internet]. 2014. p. 1. Available from: https://www.npr.org/sections/parallels/2014/05/19/313982248/for-brazils-soccer-stars-careers-often-begin-on-makeshift-fields

63. Mello J, Pedretti A, Caporal G, Mahique J, Ferreira A, Reppold-Filho A, et al. Secular trend of sports practice of Brazilian children and young people in the decade of mega-sport events. J Hum Sport Exerc [Internet]. 2020 Nov; 17(1). Available from: http://hdl.handle.net/10045/108081

64. Altmann H. Educação física escolar: relações de gênero em jogo. 1st ed. São Paulo: Cortez Editora; 2015. 153 p.