Sex differences in 3-to-5 year-old children's motor competence: a pooled cross-sectional analysis of 6241 children

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Abstract

There is some, albeit inconsistent, evidence supporting sex differences in pre-schoolers' motor competence (MC), with these observations not uniform when analyzed by age, and cultural groups. Thus, this study examined sex differences across ages in 3- to 5- year- old children's MC. A cross- country pooled sample of 6241 children aged 3–5 years (49.6% girls) was assessed for MC using the Test of Gross Motor Development—2nd/3rd edition, and children were categorized into groups of age in months. Multiple linear regression models and predictive margins were calculated to explore how sex and age in months affect scores of MC (i.e., locomotor and ball skills), with adjustments for country and BMI. The Chow's Test was used to test for the presence of a structural break in the data. Significant differences in favor of girls were seen at 57–59 and 66–68 months of age for locomotor skills; boys performed better in ball skills in all age periods, except for 42–44 and 45–47 months of age. The higher marginal effects were observed for the period between 45–47 and 48–50 months for locomotor skills ($F = 30.21$; and $F = 25.90$ for girls and boys, respectively), and ball skills ($F = 19.01$; and $F = 42.11$ for girls and boys, respectively). A significantly positive break point was seen at 45–47 months, highlighting the age interval where children's MC drastically im- proved. The identification of this breakpoint provides an evidence- based metric for when we might expect MC to rapidly increase, and an indicator of early delay when change does not occur at that age.

1 Introduction

Early childhood is a critical period for the development of motor competence (MC) (Clark and Metcalfe, 2002), a multidimensional latent construct generally operationalized through the proficiency in performing fundamental motor skills (FMS). FMS are basic movement patterns that form the foundation for more advanced skills required for participation in organized and non-organized physical activities and sports (Goodway et al., 2019). FMS need to be fostered, learned, practiced, and developed (Gagen and Getchell, 2006) from an early age, and to be consolidated and strengthened over the years (Clark and Metcalfe, 2002). Age-adequate levels of MC during childhood have been linked to more physical activity levels, healthy weight status (Barnett et al., 2022; Martins et al., 2023), increased physical fitness (Behan et al., 2022), which may result in increased health benefits during later childhood and adolescence (Bornstein and Hendricks, 2013). Emerging evidence also suggests MC may moderate the effect of cognitively enriched physical activity on cognitive outcomes, in particular, working memory and social-emotional skills. higher cognitive skills, and higher socio-emotional skills (Hill et al., 2023). Conversely, delayed MC can have long-lasting adverse effect on health outcomes, and limit chances for successful participation in physical activity.

Children´s and adolescents´ MC levels are lower than desirable worldwide (Bolger et al., 2021). Considering that MC is determined by individual, social, and environmental factors (Barnett et al., 2016a), it is crucial to identify and target specific population groups that are more likely to have low levels of MC. In this sense, it is well-known that sex has been highlighted as an important correlate of MC (Barnett et al., 2016a). Prior studies with children and adolescents reported in the Barnett et al. meta-analytic review stated that the association between sex and MC depends on age and on the skill domains (i.e., locomotor or ball skills); in favor of boys for object control skills. During the preschool years, the absence of defining phenotypical sex characteristics could lead to differences between male and female preschoolers´ MC. Yet there is some, albeit inconsistent, evidence supporting sex differences in preschoolers´ MC (Mecías-Calvo et al., 2021; Olesen et al., 2014; Jelovčan and Zurc, 2016; Veldman et al., 2017), with these observations not uniform when analyzed by age (Kokštejn et al., 2017), and cultural groups.

In 2014, Iivonen and Sääkslahti (2014) reviewed the determinants of MC among preschoolers aged 3-6 years and reported that boys performed better than girls in ball skills, whilst girls performed better in stability and locomotor skills. It should be noted that these results were based on studies that used MC assessment tools. Focusing only on Test of Gross Motor Development (TGMD), Zheng et al. (2022) conducted a systematic meta-analytic review examining sex differences in MC among 3-6 year old children. Results for overall MC based on 16 studies including 1351 boys and 1247 girls highlighted significant differences favoring boys (95% CI 0.03, 0.31; $p = 0.02$). Further, results based on data from 38 studies and more than eight thousand children highlighted no differences in locomotor skill proficiency (95% CI 0.15, 0.01; $p = 0.09$), and significant differences in favor of boys for ball skills (95% CI 0.38, 0.58; $p < 0.001$), which notably increased with age. In fact, proficiency in ball skills has been systematically associated with older boys (Bolger et al., 2021), though the abovementioned systematic reviews usually merged preschool children (3 -to-5 years - old) with 6 year-old children in the same group. This leads to caution in the studies´ conclusion (Zheng et al., 2022), as the early years of life comprises a period of rapid growth and development (WHO, 2019). Indeed, the global picture of the association between MC and sex during the preschool years is unclear because evidence covering this period of life is generally focused on specific age groups (i.e., 3-to-5 years-old). This means that the relationship between MC and sex during the spectrum of the preschool period is still unknown. Moreover, whether there are critical age periods in which this association is more or less strong is also unknown. To the best of the authors´ knowledge, no research has investigated MC development in terms of age in months and associated sex differences. How these variables are related across theses. It means that information on the pattern of The exception is when motor skill data is collected to create instrument norms. For example, the TGMD - 2nd Edition (TGMD - 2) had a sample of 1208, and the 3rd Edition (TGMD - 3) collected data from 862 children. However, these normed datasets only collected data on 322 children from the ages of 3 to 5 years of age (TGMD-2), and 370 children (TGMD-3). Moreover, the datasets were designed to be reflective of the United States population (Ulrich, 2018), and therefore may not be generalizable to children in other countries.

Recognizing sex differences in preschoolers´ MC should be actively sought if we aim to promote an equitable increase in children´s MC, because sex disparities are reduced if girls have the same opportunities for mentoring, feedback, practice, and encouragement (Palmer et al., 2020; Zask et al., 2012). The inconsistencies of the body of literature do not allow for conclusive statements regarding sex differences in preschoolers´ MC, especially from an international perspective. This reinforces the need for detailed international information on the MC-sex association in the preschool years, to conceive and implement tailored healthy development promotion actions and policies. Moreover, cross-cultural pooling of the data allows a solid picture of MC development around the world. Thus, this study examined sex differences across ages in 3-to-5 year-old children´s MC. To do this we analyzed a cross-country pooled sample of 3-5 year-old children from nine countries.

2 Methods

2.1 Data sources and participants

This study included data of 3-5 year-old children, aligning with the preschool age range in most countries. The process of developing a data pool has been described previously (Martins et al., 2023). In brief, from December 2020 up to mid-September 2021, possible collaborators who had assessed 3-to-5 year old preschoolers before the COVID-19 lockdown, with the widely used, validated, and reliable TGMD-2 or TGMD-3 between 2010 and 2020, were sought and identified using the following methods: (i) an extensive search on international databases (Web of Science, PubMed, and Scopus) of the motor competence/competence literature in preschool years; and (ii) a list of contacts of the International Motor Development Research Consortium – I-MDRC (https://www.i-mdrc.com). Additionally, bibliographic references of the studies identified in the databases were searched. A total of 39 possible collaborators from 28 countries (Australia, Belgium, Brazil, Canada, Chile, China, Colombia, England, Finland, Germany, Greece, Indonesia, Iran, Ireland, Italy, Macedonia, Malaysia, Mozambique, Netherlands, New Zealand, Norway, Portugal, Spain, South Korea, South Africa, Turkey, USA, and Wales) were identified.

Preschoolers' data from 20 collaborators, in nine countries (Australia, Belgium, Brazil, China, England, Iran, Italy, Spain, and USA), from three of the six WHO regions (East Asia & Pacific, Europe & Central Asia, Eastern Mediterranean, and Latin America & the Caribbean), and two country specific income levels, according to the World Bank (high and upper-middle) are reported in this study (Hamadeh et al., 2021).

Data from each collaborator were shared, and securely stored in a cloud store administered by Coventry University (UK). Data sets from the same country were merged to facilitate the analysis, thereby operationalizing a country-specific condition as a unit of clustering. The pooled data included 6241 preschoolers (49.6% girls), aged 3-5 years. A flow diagram presenting details about the datasets included is shown in Fig 1.

The smallest country samples were from Iran (n = 115), and Spain (n = 103), while the largest samples were from Australia (n = 1288), and Italy (n = 1338). Almost all participating countries obtained data from varying locations, with the exception of Spain and England. Three participating countries (Brazil, China, and USA) provided information from both the 2nd and 3rd editions of the TGMD protocol.

******************* Insert Figure 1 *******************

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies were adhered to report the results (Richards, 2007). Ethics committees in each of the respective countries approved all the primary studies, ensuring that written informed consent from all parents/ guardians was provided for the original study, and took permission´s responsibility for sharing data for the secondary data analysis.

2.2 Measurements

In all studies, weight and height were assessed using internationally well stablished protocols. Child's sex, body mass index (BMI), and age in months were provided and age was recategorized into three-month groups. Sex and age in months were used as independent variables in the regression models.

Data on MC, including the assessment protocol, were shared by each country contact. For this, the TGMD-2 (Ulrich, 2000a) and the TGMD-3 (Ulrich, 2018) were used. The TGMD evaluates gross motor performance in children aged 3 to 10 years, and consists of a protocol to assess process-oriented MC during childhood, including in preschool children. The TGMD involves a comprehensive battery of gross motor skills comprising both locomotor and object-control skills.

The TGMD-2 consists of a two-factor test, with six locomotor skills (run, gallop, hop, leap, jump, and slide) and six object control skills (strike, bounce, catch, kick, overhand throw, and underhand roll). The TGMD-3 test also consists of two factors, but with 13 total skills, six locomotor skills (run, gallop, hop, skip, horizontal jump, and slide) and seven object control skills (one-hand strike, two-hand strike, dribble, catch, kick, overhand throw, and underhand throw). The criterion validity of the TGMD-3 and the TGMD-2 showed nearly perfect positive correlations between locomotor skills, ball skills and total scores (all r =.98) (Ulrich, 2018).

According to the procedures, children practiced each skill and then performed each skill twice. For each trial, a child receives a score of “1” if the performance criteria for that skill (e.g., *stepping with foot opposite throwing arm*) is performed correctly and a score of “0” if the criterion is performed incorrectly. The locomotor and ball skills scores are based on the presence (one) or absence (zero) of each performance criteria to calculate the summed raw scores. In all but one of the original projects, each collaborator´s team video-recorded all the trials and later these were assessed by trained assessors who had prior experience coding this assessment. The exception is for Belgian children, who were assessed live (not through video recording) (Bardid et al., 2016). All collaborators who participated in the project had experience in motor development research and significant experience in using, analyzing, and interpreting motor skill assessments like the TGMD. Evidence of TGMD assessment reliability was previously presented in the primary original studies from six countries (Spain, Italy, Brazil, Australia, Iran, and USA) (Estevan et al., 2022; Magistro et al., 2020; Mota et al., 2020; Bardid et al., 2016; Valentini, 2012; Valentini et al., 2017; Salami et al., 2021; Bandeira et al., 2020; Garn and Webster, 2021; Barnett et al., 2016b).

2.3 Statistical analysis

All analyses were performed in Stata 18.0. Data from countries were pooled into a single dataset for analyses, performed for the whole sample. No information imputation was performed, and missing data, corresponding to 3.9% of the total sample, were excluded for analysis (detailed information in Supplementary Table 1). Then, data were stratified by age and sex. Data normality and homogeneity tests were conducted.

To analyze how sex and age in months affect MC, two multiple linear regression models were conducted considering sex and age as the independent variables, and summed raw scores of MC (i.e., locomotor and ball skills) as the dependent variables, with adjustments for country as a categorical variable, and continuous values for BMI. The interaction between sex and age was tested. Predictive margins, derived from the statistical regression model, were calculated for the mean predictions of MC (locomotor skills and ball skills), which provide an average prediction of MC values for each age group and sex, controlling for the other variables in the regression model. Subsequently, to assess if significant differences exist in the domains of MC between each sex and age group, they were estimated using predictive margins. Then, the slope resultant of the increment / decrease of MC domains in all pairs of age groups was calculated as follow: $m = (y_2-y_1) / (x_2-x_1)$, selecting the one with the steepest slope. Finally, the Chow´s Test (Chow, 1960) was used to test for the presence of a structural break in the data at an a priori known period of age (the one with the highest calculated slope). For example, if the contrasts are significant for the interval between 36-38 months, and the slope was the highest observed, this would suggest a structural break point, if the Chow's test was significant.

3 Results

Preschoolers (N = 6241; 50.4% boys) were of a similar age (mean age: 54.36 ± 9.15 months). Descriptive results and the predictive margins showing differences between sexes for locomotor skills and for ball skills, and explained variance means with 95% confidence intervals were calculated and depicted for every age, using the regression coefficients (Table 1; Figure 2). Results show that while significant differences in favor of girls were seen for those at 57-59 and 66-68 months of age for locomotor skills; boys performed better in ball skills in all assessed age periods, except for 42-44 and 45-47 months of age.

******************** Insert Table 1 ********************

******************** Insert Figure 2 ********************

Results of the predictive margins calculated to test the differences between pairs of age groups indicated significant differences between months with the higher marginal effect observed for the period between 45-47 and 48-50 months for locomotor skills ($F = 30.21$; and $F = 25.90$ for girls and boys, respectively), and ball skills ($F = 19.01$; and $F = 42.11$ for girls and boys, respectively) (Table 2).

******************* Insert Table 2 *******************

The slopes resultant of all pairs of age intervals were tested as breakpoints in children´s MC. Results showed a significantly positive breakpoint, exhibiting 45-47 months as the age interval where children´s performance in locomotor (Chow´s Test: $F(4,2792) = 12.59$, $p < 0.001$ and $F(4,2737) = 19.21$, $p < 0.001$) for boys and girls, respectively), and ball skills (Chow´s Test: $F(4,2792) = 7.14$, $p < 0.001$, and $F(4,2737) = 14.87$, $p < 0.001$, for boys and girls, respectively) drastically improved (Figure 3).

******************* Insert Figure 3 *******************

4 Discussion

We examined sex differences across ages in 3-to-5 year-old children´s MC. Our main findings highlighted that first, there was a clear increase in children's MC with age. Secondly, boys and girls maintained a similar score in locomotor skills, with the exception at 57-59 and 66-68 months of age (4.75 – 4.92; and 5.5 – 5.67 years of age, respectively), wherein girls outperformed boys. Third, boys exhibited higher ball skills scores than girls, and this was evident right from 3 years old. Girls maintained similar increases over time, however, the difference in ball skills between boys and girls remained, and even increased at the end of preschool. Finally, between 45-47 months (3.75 - 3.92 years of age), a positive breakpoint was detected, demonstrating that children´s performance in locomotor and ball skills, for both boys and girls, drastically improved at this point in their early development. The identification of this breakpoint represents a step change in work examining sex differences in MC, providing an evidence-based metric for when we might expect MC to rapidly increase, and an indicator of early delay when change does not occur at that age.

Our results regarding an increase in FMS with age reflects developmental validity. As children age, they tend to have higher FMS scores, as they are able to engage in more movement experiences and opportunities to enhance their skills, based on opportunities, practice and / or maturation. This is also evidenced in the correlations' values observed in the TGMD-2 (Ulrich, 2000b) normative data (r = .69 for locomotor, and r = .71 for object control skills). In TGMD-3 normative data, this correlation is considered large for locomotor skills (r = .65 and r = .62 for males and females, respectively), and very large for ball skills (r=.74 and r=.76 for males and females, respectively.

In terms of patterns, our study, using the same tool to assess MC in children from different cultural backgrounds showed similar scores for locomotor skills between boys and girls until the middle of the 4th year of life, where girls outperformed boys. This differed slightly from the published normative data trends. The norms for the TGMD-2 showed a slightly different picture, in that for locomotor skills, boys consistently performed lower in terms of raw scores at three years (19 to 21) and four years of age (27 to 29), and then became more similar in scores at five years (33 to 32). In the TGMD-3 norms, similar patterns were seen for locomotor skills, where boys showed lower values than girls at three years of age (15 to 19), at four years of age (22 to 23), and at five years (29 to 30). This pattern changes for the ball skills. In the current study, boys performed ball skills better than girls from three years of age, and girls´ MC in ball skills never overtook boys after this time point. As such, the differences between boys and girls concerning ball skills performance remained, and even increased at the end of the examined age period. This pattern is also reflected in the TGMD-2 norms. For 3-to -5 years-old, boys had higher object control raw scores than girls at the age of three (20 to 17, and four (25 to 22), and this difference increased at the age of five 5 (30 to 25). The most recent meta-analytic review on the topic (Zheng et al., 2022), which covered children aged 3 to 6 years, found similar evidence to the current study with regard to skill patterning by sex. Other studies have shown that object control skills are typically better in boys (Zheng et al., 2022; Foulkes et al., 2015; Spessato et al., 2013; Jacqueline D et al., 2014), but (LeGear et al., 2012) locomotor skills are less consistent in sex patterning. These inconsistencies could be attributed to the different protocols used, to individual variabilities, and to cultural differences.

The authors of the aforementioned meta-analysis discussed the results based on a phylogenic perspective, arguing that sex differences observed in ball skills might be related to boys being more likely to use finely segmented pelvic–torso–shoulder rotation when doing skills such as throwing (Butterfield et al., 2012), which is related to a warrior background in men and their hitting behaviors, from an evolutionary approach. The suggestions made by Butterfield et al (2012), in taking an evolutionary perspective to explain sex differences in children's gross MC are interesting, though this approach seems speculative considering the average 21st century man is far from a warrior.

There are other potential explanations of why sex differences in gross MC may be observed. Kokstejn et al (2017) analyzed sex differences in MC through the Movement Assessment Battery for Children–second edition in a sample of 325 preschoolers (4.9 ± 1.1 y, range 3–6), and observed that differences are not uniform throughout the whole preschool period, when analyzing by age. The authors discussed the results based on maturational differences between sexes. Girls and boys are exposed to distinct brain maturational processes, which could, at least partially, explain the observed differences. For example, there is a brain area that propels many boys toward things that move, and many girls toward nurturing (Taylor, 2014). Thus, boys' gross motor skills could tend to develop slightly faster, while girls' fine motor skills improve first. A previous study with 4- to 11-year-old children showed that young girls have greater fine motor skills (Flatters et al., 2014) required in activities demanding a high degree of precision, such as those which typically involve fine manipulation of objects. For instance, in middle childhood, girls seem faster and better synchronized in fine motor skills than boys (Denckla, 1973). For this reason, girls may be interested in art (painting, coloring, crafts) before boys. Also, the brain´s pleasure center essentially lights up more for boys when they take risks, what could lead them to experiment different and challenging activities. That is not to say that girls are not active risk-takers, only that, on average, boys are more so, and individual variation and experience also matter. Moreover, from a biological perspective, male babies are born with as much testosterone as a 25-year-old man, and after birth, testosterone plummets until a boy reaches puberty. Thus, boys are also more physically aggressive and impulsive, as revealed by studies of their brains (Miu et al., 2019).

The environmental opportunities and affordances children have available to them are essential in terms of developing motor skills. In an Australian cross-sectional study in preschool children, homes with more skill related-toys and equipment also had children with better motor skills (Barnett et al., 2013). Another Australian study showed that more home equipment for physical activity and motor skills development when a child was nine months and 3.5 years-old was predictive of better object control skills (Barnett et al., 2019). Although this does not explain why boys would have more opportunities than girls to develop ball skills performance, the study shows that early supportive environmental opportunities are important to make a difference to both boys’ and girls’ MC, starting from the early years of life. In this sense, parents/caregivers´ implicit gender bias in providing children with toys that align with gender stereotypes could lead to these initial proclivities.

It is probable that there is also an ontogenetic explanation, in which boys are encouraged and given more consistent opportunities from a young age to play with balls and ball-related objects, thereby socialized by parents or significant others, to engage in more object control activities. For example, parents of girls have traditionally provided less encouragement for physical activity, offered fewer sport-related opportunities for their daughters compared to their sons, and perceived their sons to have higher sport competence than their daughters (Fredricks and Eccles, 2005). These factors may exacerbate differences in the opportunities provided for females and males in the early years. Thus, given that the detection of specific motor deficits in young children might be of extreme importance for their overall development, in practical terms, it means that we would need focus on interventions to promote girls´ proficiency in gross ball skills, but also to explore ball skills that girls are more interested and motivated to be engaged, in order to diminish the observed sex differences along the analyzed periods.

Gender differentiated behaviors emerge early in development, with children demonstrating an understanding of gender categories (Ruble et al., 2007). Thus, girls might not be challenged or afforded with opportunities to develop their ball skills for much of the time, when compared to boys. Nonetheless, we need to consider that it may not be just a matter of lack of external stimuli, but also of girls' individual choices, which are likely greatly influenced by social gender stereotypes. Based on social cognitive theorists, gender socialization is the consequence of observational learning and social reinforcement (Bussey and Bandura, 1999; Ruble et al., 2007). For instance, Miedema et al (2023) assessed 84 children aged three years four months to five years seven months to explore associations between children's stereotypes and actual object control skills performance. Results showed that girls highlighted higher gender stereotypes about who should do object control skills, in conjunction with having lower object control skill performances. In another study exploring how parents' promotion of play may impact gender differences in motor development in infants, parents of males more frequently made statements to promote gross motor skills while parents of females more frequently made statements to promote fine motor skills (Dinkel and Snyder, 2020). The abovementioned findings show that stereotyping starts very early in infancy. Risk taking can be examined from this perspective. A study in French preschool children showed that boys' and girls' injury-risk behaviors were predicted by how much children conformed to masculine stereotypes (Granié, 2010). Another study in American preschoolers reported that fathers were more careful of their daughters around potential risks than their sons, thereby helping to form girls' perspectives about the ability to take risks.

Although age-related changes and improvements are expected during the preschool years, our results did not reveal significant differences between all the age periods examined. Although categorizing in 3-months increments allows for a finer-grained analysis of age-related developments, the absence of age-related differences in locomotor and ball skills during some periods probably indicates that the 3-month intervals examined were not sufficient to reveal significant changes in children´s MC. Nonetheless, the interval between 45-47 months of age was highlighted as an important breakpoint of children´s performance in locomotor and ball skills for both boys and girls. This period may coincide with the start of care/preschool for many children. In early childhood care and education settings, it may also be explained by children being able to go outside or engage in more varied play with equipment. Another possible social cultural explanation is that in some countries, this period corresponds to a child´s eligibility to engage in organized sports in some cultures. A needed next step is to explore in greater depth, the reasons for this breakpoint, and if it is uniform for all the assessed skills, or MC domains, such as stability, even using different protocols. Future studies should also focus on understanding environmental aspects that could modify the observed patterns, such as children´s attendance at childcare centers, participation in organized sports, and parental support for physical activity, for example.

5 Perspectives

The examination of sex differences in MC is not new. However, the present study provides a larger overview of sex differences in gross locomotor and ball skills than has been the case previously. The identification of a distinct breakpoint in children´s MC at 45-47 months of age represents a new insight in the literature related to motor development in early childhood. Such new information is crucial for researchers, scientists, practitioners, and pediatricians working in the field. A further understanding of this aspect of sex differences can subsidize the development of effective interventions to harness the accelerated motor development associated with the breakpoint. It can also help identify delays in motor development post breakpoint, that may be modifiable through effective practice and feedback, whilst also gaining insight in how sex differences between boys and girls may be minimized.

Author contributions

C.M.: conceptualization, data curation, formal analysis, visualization, methodology, project administration, writing - original draft. V.R.P.: conceptualization, formal analysis, visualization, methodology, writing - review & editing. E.K.W. and M.D.: data curation, project administration, supervision, writing - review & editing. L.F.L.: conceptualization, formal analysis, methodology, writing - review & editing. A.S., A.O., D.M., F.B., I.E., J.M., L.E.R., M.L., S.C., N.V.: data curation, supervision, writing - review & editing

F.C., F.M, K.N., M.Q., P.C., R.J., R.H., Y.D.: data curation, writing - review & editing

P.R.B.: conceptualization, data curation, formal analysis, methodology, writing - review & editing. L.B.: conceptualization, data curation, methodology, supervision, writing - original draft

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Table 1. Descriptive data using marginal effects for comparing sex and age groups.

Age (months)	LOCOMOTOR SKILLS (score)					BALL SKILLS (score)				
	Boy	**95% CI**	**Girl**	**95% CI**	**Total**	**Boy**	**95% CI**	**Girl**	**95% CI**	**Total**
36-38	14.06 ± 8.85	12.72; 15.41	13.56 ± 8.20	12.20; 14.92	13.81 ± 8.52	14.72 ± 9.12	13.44; 16.01	11.00 ± 6.93***	09.70; 12.30	12.88 ± 8.31
39-41	14.05 ± 8.00	12.66; 15.44	13.25 ± 7.76	11.81; 14.69	13.67 ± 7.88	14.38 ± 8.15	13.05; 15.71	11.95 ± 7.73*	10.58; 13.33	13.21 ± 8.03
42-44	15.23 ± 8.58	13.92; 16.53	14.96 ± 8.64	13.61; 16.31	15.10 ± 8.60	14.86 ± 8.24	13.61, 16.11	13.33 ± 7.66	12.05; 14.62	14.12 ± 7.99
45-47	17.51 ± 8.79	16.38; 18.64	16.96 ± 8.90	15.74; 18.18	17.26 ± 8.84	16.73 ± 7.85	15.65; 17.81	15.24 ± 7.80	14.08; 16.41	16.04 ± 7.86
48-50	21.58 ± 9.86	20.55; 22.62	21.38 ± 10.15	20.39; 22.38	21.48 ± 10.00	21.95 ± 9.24	20.96; 22.93	19.05 ± 9.43***	18.11; 19.99	20.44 ± 9.44
51-53	22.18 ± 9.96	20.97; 23.38	21.15 ± 10.06	20.09; 22.21	21.60 ± 10.02	22.55 ± 9.78	21.39; 23.70	18.04 ± 9.76***	17.03; 19.05	20.00 ± 10.01
54-56	22.45 ± 9.93	21.47; 23.42	23.50 ± 9.50	22.58; 24.42	23.00 ± 9.71	22.26 ± 9.23	21.33; 23.18	19.22 ± 8.86***	18.34; 20.10	20.65 ± 9.16
57-59	22.18 ± 8.43	21.24; 23.11	24.28 ± 8.44**	23.36; 25.20	23.25 ± 8.49	22.14 ± 8.18	21.25; 23.03	18.87 ± 6.98***	17.99; 19.74	20.48 ± 7.76
60-62	25.80 ± 8.13	25.02; 26.59	26.25 ± 7.86	25.41; 27.08	26.01 ± 8.01	25.11 ± 8.43	24.36; 25.85	21.87 ± 8.10***	21.07; 22.66	23.59 ± 8.43
63-65	25.26 ± 9.03	24.03; 26.49	26.35 ± 9.24	25.08; 27.61	25.79 ± 9.13	24.73 ± 9.67	23.55; 25.91	21.80 ± 8.57***	20.59; 23.01	23.32 ± 9.26
66-68	24.21 ± 9.43	23.22; 25.19	25.76 ± 9.08*	24.69; 26.83	24.92 ± 9.29	26.52 ± 9.13	25.58; 27.45	23.24 ± 8.04***	22.23; 24.26	25.01 ± 8.79
69-71	27.17 ± 9.50	25.79; 28.56	27.86 ± 9.06	26.40; 29.32	27.50 ± 9.29	28.82 ± 9.82	27.50; 30.14	23.80 ± 8.57***	22.41; 25.19	26.44 ± 9.57

Note. * p<0.05; ** p<0.01; *** p<0.01

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Table 2. Marginal effects for comparisons between pairs of age intervals and sex

Age intervals (months)	**N**		**Locomotor skills**				**Ball skills**			
			Girls		**Boys**		**Girls**		**Boys**	
	Girls	**Boys**	**F**	**p**	**F**	**p**	**F**	**p**	**F**	**p**
39-41 vs 36-38	150 vs 168	161 vs 172	0.02	0.882	0.12	0.728	1.96	0.162	0.46	0.500
42-44 vs 39-41	172 vs 150	182 vs 161	2.70	0.101	0.90	0.342	1.77	0.165	0.29	0.591
45-47 vs 42-44	209 vs 172	244 vs 182	4.36	<0.037*	5.86	0.016*	4.48	0.034*	5.22	0.022*
48-50 vs 45-47	317 vs 209	291 vs 244	30.21	<0.001*	25.9	<0.001*	19.01	<0.001*	42.11	<0.001*
51-53 vs 48-50	278 vs 317	214 vs 191	0.76	0.382	0.96	0.326	0.64	0.424	1.49	0.222
54-56 vs 51-53	368 vs 278	330 vs 214	11.28	<0.001*	0.00	0.979	2.28	0.131	0.420	0.515
57-59 vs 54-56	368 vs 369	357 vs 330	1.96	0.162	0.13	0.714	0.21	0.646	0.06	0.799
60-62 vs 57-59	447 vs 369	508 vs 357	5.37	<0.021*	34.97	<0.001*	13.96	<0.001*	25.20	<0.001*
63-65 vs 60-62	194 vs 447	205 vs 508	0.60	0.438	0.48	0.489	1.00	0.317	0.03	0.872
66-68 vs 63-65	274 vs 194	322 vs 205	5.27	0.017*	1.64	0.200	3.44	0.063*	4.96	0.026*
69-71 vs 66-68	146 vs 274	162 vs 322	0.58	0.446	1.50	0.221	0.05	0.830	7.88	0.005*

Note: * p<0.05

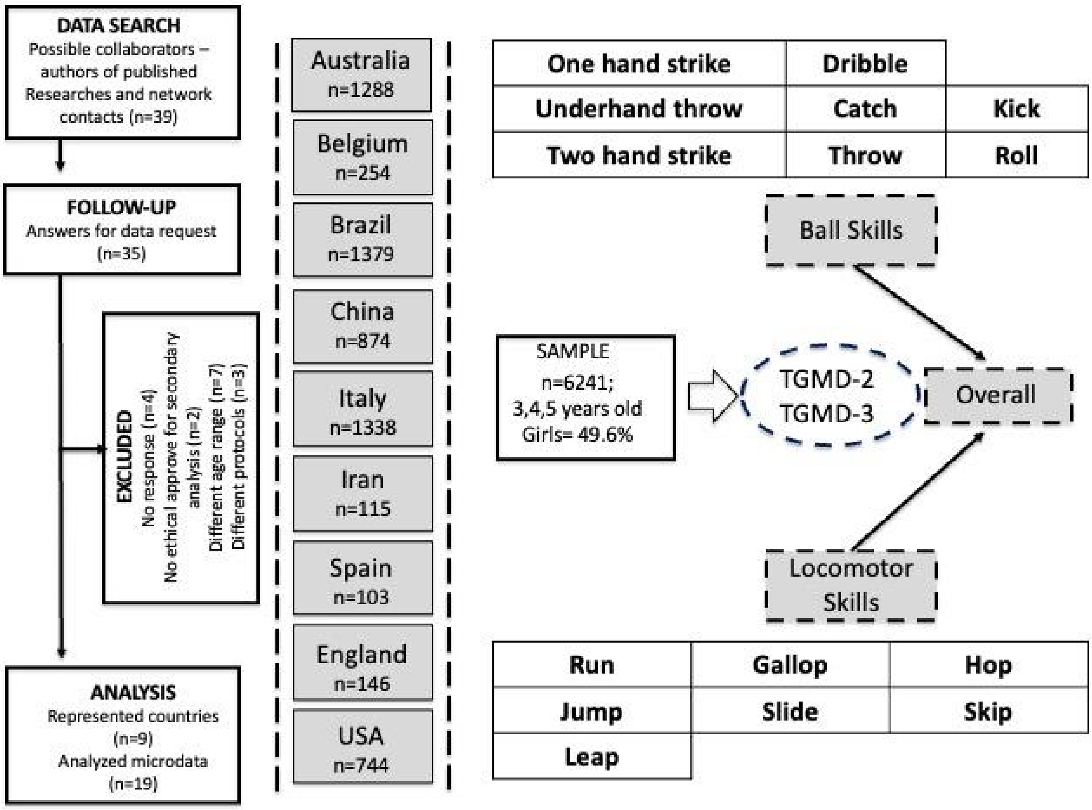

Figure 1. Flow diagram for inclusion in the study.

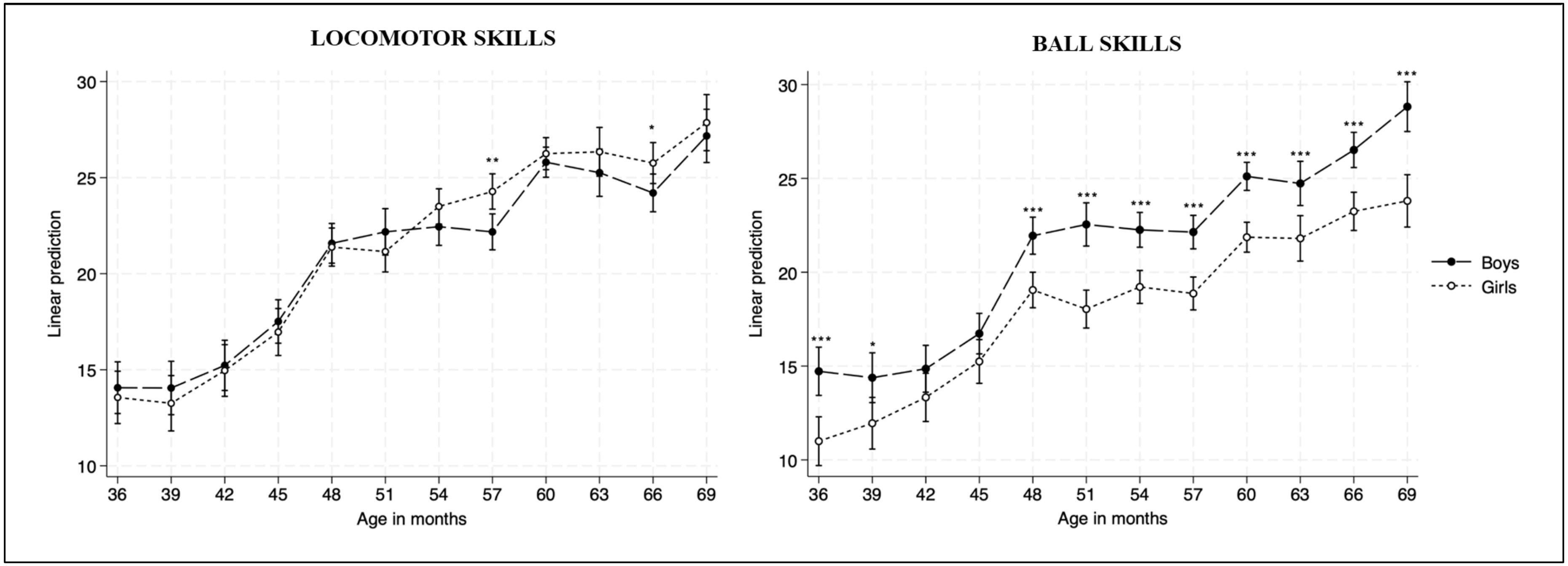

Figure 2. Linear regression models between sex and motor competence according to age in months, with adjustments for country and body mass index. * p<0.05; ** p<0.01; *** p<0.01

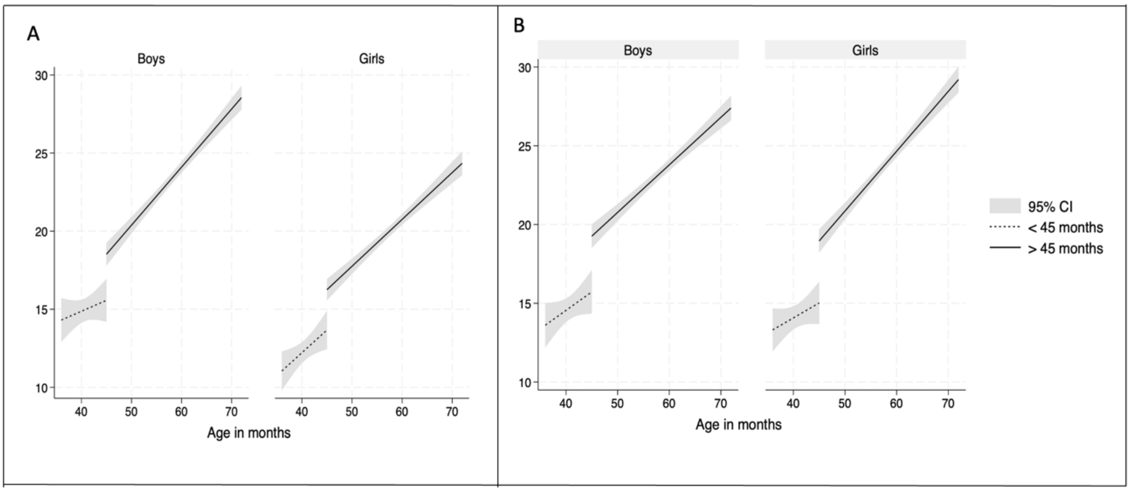

Figure 3. Breakpoint for locomotor (Panel A) and ball skills (Panel B) by sex.

Supplementary Table 1: Data source

Income Level	WHO region	Country (N)	Year of assessment	City/Region	Ethics Approval	Protocol	N (%)
Upper-Middle	Americas	Brazil	2012/2016	Lagoa do Carro	2.520.417	TGMD - 2	1379 (22.1)
			2016	Porto Alegre	2.007.698		
			2016	Juazeiro do Norte	2.683.488		
			2019/2020	João Pessoa	2.727.689	TGMD - 3	
			2018	Juazeiro do Norte	4.330.160		
	Western Pacific	China	2017 2019	Shangai, Yangpu Xi´Na, Shananxi	22BTY099	TGMD - 2 TGMD - 3	874 (14.0)
	Eastern Mediterranean Region	Iran	2017	Tehran	IR. SSRI. REC. 1399.728	TGMD-3	115 (1.8)
High	Western Pacific	Australia	2015 2013	New South Wales Melbourne	HE14/137 EC 175-2007; CDF/07/1138	TGMD - 2	1288 (20.6)
	European	Belgium	2012	West Flanders East Flanders Flemish Brabant Antwerp	2012/848	TGMD - 2	254 (4.1)
		England	2018	Coventry	P45654	TGMD - 2	146 (2.3)
		Italy	2016/2018	Asti Cirie Dronero S. Francesco S. F. Al Campo Torino Venaria	100949	TGMD - 3	1338 (21.4)
		Spain	2019/2020	Valencia	H1446557620395	TGMD - 3	103 (1.6)
	Americas	USA	2012 2017/2019	Opelika Baton Rouge Detroit	10-217 MR 1009 2015-044-PBRC; 2018-041-PBRC HUM00133319	TGMD - 2 TGMD - 3	744 (11.9)

Note: TGMD – 2 = Test of Gross Motor Development 2nd edition; TGMD – 3: Test of Gross Motor Development 3rd edition.; WHO = World Health Organizations.