TGMD-2 short version: evidence of validity and associations with sex, age and BMI in preschool children

Bandeira, P., Duncan, M., Pessoa, M. L., Soares, I., da Silva, L., Mota, J. & Martins, C.

Original citation & hyperlink:
Bandeira, P, Duncan, M, Pessoa, ML, Soares, I, da Silva, L, Mota, J & Martins, C 2020, 'TGMD-2 short version: evidence of validity and associations with sex, age and BMI in preschool children', Journal of Motor Learning and Development, vol. (In-press), pp. (In-press).
https://dx.doi.org/10.1123/jmld.2019-0040

DOI 10.1123/jmld.2019-0040
ISSN 2325-3193
ESSN 2325-2367

Publisher: Human Kinetics

TGMD-2 SHORT VERSION: EVIDENCE OF VALIDITY AND ASSOCIATIONS WITH SEX, AGE AND BMI IN PRESCHOOL CHILDREN.

Paulo Bandeira *(Corresponding author)* paulo.bandeira@urca.br, Regional University of Cariri, Crato, Brazil.
Michael Duncan - aa8396@coventry.ac.uk , Coventry University, West Midlands, UK
Maria Luiza Pessoa - maluedf@gmail.com, Federal University of Paraíba state, Brazil.
Ívina Soares - ivinaaires@hotmail.com, Education Department of Ceará state, Brazil
Larissa da Silva - larissa.nunessilva@hotmail.com, Regional University of Cariri, Crato, Brazil.
Jorge Mota - jmota@fade.up.pt, University of Porto, Portugal
Clarice Martins - claricemartinsufpb@gmail.com, Federal University of Paraíba state, Brazil.

April, 22nd 2020

TGMD-2 SHORT VERSION: EVIDENCE OF VALIDITY AND ASSOCIATIONS WITH SEX, AGE AND BMI IN PRESCHOOL CHILDREN.

Aim: To analyze the evidence of validity and reliability of the TGMD-2 for low-income preschoolers; and to investigate the associations between the final model with sex, age and BMI. **Methods:** 368 preschoolers (3-5 years; 4.80±0.48; 176 boys) located in deprived areas were assessed for anthropometric measures and motor competence via the TGMD-2. A two-factor model (12 skills) was used and confirmatory indexes were calculated. The Bayesian criteria and the Composite Reliability were employed to evaluate alternative models. Relationships between the final model proposed with age, sex and BMI were calculated using a network analysis (Mplus 8.0; Rstudio). **Results:** A two-factor model (locomotion and object control) with adequate values (> 0.30) for the six skills (gallop, leap, slide, strike, throw and roll) and presented excellent indexes. Relationships between sex and throwing (r = -. 22), and strike (r = -. 21), indicated better performance for the boys. Positive relationships were found for age with slide (r = 0.23) and hop (r = 0.28) and for BMI with throw (r = 0.18). **Conclusion:** Validity of a TGMD-2 short version for low income preschoolers was presented. The machine learning analysis to associate FMS with gender, age and BMI seems useful to optimize future interventions.

1. INTRODUCTION

Fundamental movement skills (FMS), the principal elements of motor development (Reeves, Broeder, Kennedy-Honeycutt, East, & Matney, 1999), are gross motor skills that young children acquire and develop as they age (Klingberg, Schranz, Barnett, Booth, & Ferrar, 2019). Higher competence in FMS, such as run, throw, jump, catch, for example, has been highlighted as a precondition for functioning in daily life, and participation in later physical or sport-specific activities (Stodden et al., 2008). So, FMS have emerged as a topic of considerable interest.

In early childhood, FMS develop as a function of physical maturation, practice (Goodway, Ozmun, & Gallahue, 2019), environmental opportunities (Nobre, Valentini, & Rusidill, 2020), and play an essential role in the development of children's movement patterns (Hardy, King, Farrell, Macniven, & Howlett, 2010). Any failure in age-appropriate development can limit motor skill competence, affecting children´s physical and mental health (Piek, Baynam, & Barrett, 2006). In this sense, early childhood is a critical period for the development of FMS (Hardy et al., 2010), and even during this period of life, socio-cultural correlates, such as socioeconomic status (SES), may affect children`s FMS (L. M. Barnett et al., 2016; Venetsanou & Kambas, 2010).

Although a recent study with a large sample of children from the United States indicated that motor delays are independent of SES (Brian et al., 2019), in other contexts, such as in Brazil, low-income children may have "poorer" structured and / or unstructured motor opportunities (Nobre, Bandeira, & Valentini, 2016). Subsequently, this limited exposure can subsequently impact their motor development.

The Test of Gross Motor Development (TGMD-2) (Ulrich, 2000) is one of the most frequently used assessments to evaluate process-oriented FMS during childhood and adolescence (Klingberg et al., 2019), and involves a comprehensive battery of movement skills comprising both locomotor, the skills used for the purpose of transporting the body through space, and object-control skills, which involve giving force to object or receiving force from objects. It can be used to identify children who are significantly behind their peers in gross motor performance, to plan programs to improve skills in those children showing delays, and to assess changes as a function of increasing age, experience, instruction or intervention (Ulrich, 2000). Although a valid and reliable measure, administering the TGMD-2 demands a considerable amount of time to administer and to interpret (Barnett, Hinkley, Okely, & Salmon, 2013), specifically trained staff, and a specific space is required for its assessment. These requirements often make it logistically more difficult to administer in childcare and school settings, with recent research suggesting the TGMD-2 may not be the most feasible choice in the context of preschool settings and preschool staff (Tamplain, Webster, Brian, & Valentini, 2019; N. C. Valentini, Rudisill, Bandeira, & Hastie, 2018). In this sense, a short version of the TGMD-2 will reduce administration time, facilitate the screening of children with delays in FMS, and may optimize the intervention process by teachers, technicians and researchers.

In Brazil, preschools in low-income contexts differ markedly from those in high-income environments in terms of the number of students per class, the available infrastructure and the motivation of the teachers, aspects that may compromise children's movement opportunities (Nobre, Coutinho, & Valentini, 2014). Likewise, low-income children have different motor patterns when comparing to high-income ones (Chow & Louie, 2013; McPhillips & Jordan-Black, 2007; Morley, Till, Ogilvie, & Turner, 2015; Venetsanou & Kambas, 2010). Although studies have already shown the psychometric properties of the TGMD-2 full version for preschoolers (Kim, Kim, Valentini, & Clark, 2014; Lopes, Saraiva, & Rodrigues, 2018; N. C. Valentini, 2012), FMS correlates differ according to skill category and are context specific (Barnett et al., 2013). It is therefore essential to assess how the TGMD-2 performs in different field-based contexts. Though a previous study has proposed a TGMD-2 short version for Brazilian children, data comprised children from early and later childhood (8.10±1,32 years-old) and were not low-income context-specific (Valentini et al., 2018).

Further, the Stodden et al., (2008) conceptual model includes healthy weight as a key outcome of developing motor competence. Another recent conceptual model recognizes that besides the potential cultural and geographic specificity of motor skills, personal attributes such as weight status affects lifespan motor skill development (Hulteen, Morgan, Barnett, Stodden, & Lubans, 2018), which might be seen as a key factor to consider within any model used to understand FMS trajectories.

Given the importance of FMS and its correlates for lifelong physical activity and developmental outcomes in preschool-aged children, it is important to identify which skills better represent the FMS´s construct in respect to local characteristics of low-income children in addition to how well they associate with different correlates. This study aimed to address this issue by analyzing the internal structure and evidence of validity and reliability of the TGMD-2 for a low-income sample of preschool children; and investigate the possible associations between the final model proposed with sex, age and BMI.

2. METHODS

2.1 Study Description

Data were collected as part of three different projects with low-income children and adolescents. The programs aimed to promote PA after-school classes to observe its effect on health outcomes of the participants. Data were collected from February to March 2018.

All the Helsinki Declarations' ethical aspects were followed (World Medical Association, 2013). The evaluation methods and procedures were approved by the Research Ethics Committee of Health Science Center of Federal University of Paraiba (protocol n. 2.727.698), and by the Education Board of João Pessoa city. Parent/guardian informed consent was obtained for each participating child.

2.2 Participants and settings

Preschool children aged 3 to 5-year-old (192 girls) of both genders, and regularly registered in preschools located in deprived areas of three different Brazilian states were eligible for the study.

For the purpose of this study, the deprived areas were characterized by zones where employment, health, education, and social services are scarce, and where the Human Development Index (HDI) range from 0.45 to 0.56. Of the 18 preschools originally approached, 6 declined participation (4 because they did not feel comfortable with research being conducted in their setting and 2 because they were compromised with other projects being developed in the school). Participants were randomly selected from 12 preschools who agreed in participating (6 in Paraíba, 3 in Pernambuco and 3 in Ceará).

The total sample comprised girls and boys who did not present differences for age and for anthropometric variables [mean age = 4.82 ± 0.48 years, mean height = 107.10 ± 6.42 cm, median BMI = 15.9 (15.4; 16.8) kg/m^2, and median *z*-BMI = 0.23 (-0.13; 0.78) units], who lived in deprived areas and were from low SES families: 58.5% of the mothers or fathers were unemployed and over 56% of the mothers and 44% of the fathers had finished the 9th grade or less, and receive up to one minimum salary per month.

2.3 Procedures

Anthropometry measurements

Height was directly measured to the nearest millimeter, with a portable stadiometer (Seca, 213, Germany) using the stretch stature method. Body mass was measured to the nearest 0.1kg using portable calibrated Seca 708 scales (Seca, Germany). Trained assessors took all measurements. Shoes and heavy clothing were removed before measurements. BMI was calculated from height and weight values, using the formula: weight (kg)/height (m)^2.

Test of Gross Motor Development – TGMD-2

Fundamental movement skills were assessed using the Test of Gross Motor Development - Second Edition (TGMD-2) (Ulrich, 2000).The TGMD-2 is valid and reliable for use in Brazilian children (N. C. Valentini, 2012). This test evaluates gross motor performance in children aged 3 to 10 years, and consists of two factors: six locomotor skills (run, gallop, hop, leap, jump and slide) and six object control skills (strike, bounce, catch, kick, throw and underhand roll).

The TGMD-2 was administered according to the procedures recommended for using the TGMD-2 (Ulrich, 2000). Before the testing of each skill, participants were given a visual demonstration of the skill by the researcher using the correct technique, but were not told what components of the skill were being assessed. Participants were then called individually to perform the skill twice. General encouragement but no verbal feedback on performance was given during or after the tests as suggested by the manual. All skills were video-recorded and later assessed by one trained assessor who do not administered the tests. After viewing each trial, the trained assessor analyzed each skill component. A “1” indicated that the component was present in the performance of the skill for that trial or a “0” indicated the component was not present. The video analysis was performed by two expert evaluators, obtaining high intra (ICC: 0.92-0.96) and interrater reliability (ICC: 0.93-0.98).

2.4 Statistical procedures

Descriptive analysis

Descriptive procedures were performed to describe locomotor and object control skills (mean and standard deviation), and frequency distribution to describe categorical variables (absolute and relative values).

The dataset did not present missing values. Normality was assessed through asymmetry and kurtosis. To evaluate the presence of multivariate outliers, the distance from Mahanalobilis (Marôco, 2010) was observed, using Rstudio.

Independent sample t-tests were conducted to compare anthropometric data and fundamental motor skills according to sex. The effect size was calculated from cohen´s d, values <0.2 considered small, 0.2 <d <0.5 moderate, and d> 0.5 large (Cohen, 2013).

<u>Confirmatory factorial analysis</u>

The results indicated non-multivariate normality of the data. Based on the assumption of non-normality, the robust maximum likelihood estimator was used in all the analysis procedures (Asparouhov & Muthén, 2009). A two-factor model (locomotor and object control skills), with 12 motor skills was used, as proposed in TGMD-2 protocol.

To evaluate the quality of the adjustments of the models, we used the Comparative Fit Index – CFI (Bentler, 1990) the Tucker-Lewis Index – TLI (Tucker & Lewis, 1973), the mean square error of approximation – RMSEA (Steiger, 1990) and the residual standardized mean square root – SRMR (Jöreskog & Sörbom, 1981). The Bayesian information criteria – BIC (Schwarz, 1978) was considered for the evaluation of alternative models. An adequate adjustment was considered when CFI and TLI values were> 0.90, while values of> 0.95 indicated good fit (Bentler, 1990; Hu & Bentler, 1999). RMSEA and SRMR values between 0.05 and 0.08 indicated acceptable fit, while values <0.05 indicated good fit (Hu & Bentler, 1999). Models with lower Bayesian criteria values indicated higher adjustment, when comparing to models with higher values (Byrne, 2013). Internal consistency was evaluated considering the composite reliability and the Omega Coefficient (Raykov, 2001). The Mplus 8.0 and the Rstudio (free version) were used for the analysis. The reliability analysis was calculated through Composite Reliability (CR). The CR is an indicator of the structural quality of a psychometric instrument (Fornell & Larcker, 1981; Hair, Black, Babin, Anderson, & Tatham, 2009). To calculate the CR, the parameters estimated by the structural equations modeling of the CFA are used. The CR values can be altered by the number of items in the dimension and by the homogeneity of the factorial loadings, so the cut-off point for this indicator may be questionable in dimensions with few items (F. Valentini & Damásio, 2016). An acceptable value for CR is 0.60 (Bagozzi & Yi, 1988).

<u>Network Analysis</u>

The possible relationships between the basic motor skills of the final model (gallop past, lateral running, striking, throwing over and roll) with age, sex and BMI were calculated using a "Machine Learning" technique entitled network analysis, which aims to establish relationships through multiple interactions between variables from graphical representations (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012).

In the present study we used the R package "qgraph" (Epskamp et al., 2012) to calculate and visualize the network graph. The "Fruchterman-Reingold" algorithm was applied so, data were presented in the relative space in which variables with stronger associations remain together, and the less strongly associated variables were repelled from each other (Fruchterman & Reingold, 1991). We used the pairwise Markov random field model to improve the accuracy of the partial correlation network, which was estimated from L1 regularized neighborhood regression. The least absolute contraction and selection operator was used to obtain regularization and to make the model less sparse (Friedman, Hastie, & Tibshirani, 2007). The EBIC parameter was adjusted to 0.5 to create a network with greater parsimony and specificity (Foygel & Drton, 2010).

The interaction between variables (nodes) can be assessed from three aspects: (1) betweenness centrality (connections), which is estimated from the number of times a node is part of the shortest path among all other pairs of nodes connected to the network; (2) closeness centrality, which is determined from the inverse of the distances from one node to all the others; and (3) strength (degree / centrality), which is the sum of all the weights of the paths that connect one node to the others (Epskamp et al., 2012). The qgraph package of the Rstudio (Free Version) program was used to estimate and visualize the graph.

3. RESULTS:

Boys and girls did not differ on demographic, anthropometric or FMS outcomes (all p > .05; Table 1). The effect size also showed small to moderate values for the measured variables.

Table 1. Sample´s characteristics

	Mean±SD			
	GIRLS (n=192)	BOYS (n=176)	Cohen´s *d*	TOTAL (n=368)
Age (years)	4.83±0.48	4.80±0.48		4.82±0.48
Weight (kg)	18.37±3.65	18.04±3.00	.03	18.21±3.35
Height (cm)	107.5±6.69	106.6±6.10	.14	107.1±6.42
BMI (kg/m²)	16.02±1.96	16.04±1.75	-.01	16.03±1.86
Locomotor				
Run	6.25±1.24	6.61±1.33*	-.28	6.42±1.29
Gallop	2.41±2.25	2.54±2.56	.38	2.47±2.40
Hop	3.18±2.12	3.25±1.97	-.03	3.22±2.05
Leap	3.82±1.72	4.30±1.73*	-.02	4.05±1.74
Jump	2.31±1.47	2.65±1.72*	-.21	2.48±1.60

Slide	1.88±2.34	1.85±2.07	-.01	1.87±2.21
Object control				
Strike	3.89±2.08	4.68±2.59*	-.34	4.27±2.37
Bounce	0.36±0.96	0.45±1.18	-.08	0.47±1.07
Catch	2.69±1.72	2.83±1.59	-.08	2.75±1.66
Kick	6.15±1.49	6.50±1.73*	-.22	6.31±1.62
Throw	0.47±1.06	0.84±1.44*	-.30	0.65±1.27
Roll	1.66±1.68	1.86±1.60	-.13	1.76±1.64
	Absolute frequency		Relative frequence	
State				
Paraíba	251		68.2	
Pernambuco	64		17.4	
Ceará	53		14.4	

*p<0,05 = Independent samples T Test

Step 1: Two-factors model with twelve skills

In the original two-factor model (locomotion and object control) with 12 skills, the general adjustment indexes were low. The factorial loadings of Run (0.127), Bounce (0.256) and Kick (0.035) were low (<0.30), and the correlation between the locomotion and object control factors was high (r = 0.718).

Step 2: Model re-specification with two factors and nine skills

A second model was performed by removing the skills with low factor loadings, being the new structure composed by two factors and nine skills, four in the locomotion factor and five in the object control factor. For this model, the general adjustments indexes were low. Nonetheless, slightly better than the values of the original model horizontal jump, bounce, and kick showed low factorial loadings. (<0.30).

Step 3: Re-specification of the model with two factors and six skills

After removing the low factorial loadings skills from the second model, a third model, with two factors and six skills was tested (throw, strike, slide, roll, hop and gallop). This third model presented excellent adjustment indexes and all the skill´s factorial loadings in both factors presented adequate values (> 0.30). The correlation between the two factors was moderate (0.67). The indexes of the three different analysis are shown in Table 2.

Table 2: Model´s adjustment indexes

Model	χ^2 (df)	**χ^2/df**	CFI	TLI	SRMR	RMSEA	90%CI RMSEA	BIC[b]
Robust method[r]								
Two Factor	198.716 (53)*	3.74	0. 502	0.380	0.065	0.086	0. 074- 0.099	17223.837

12 skills								
Two Factors 9 skills	115.622 (25)*	4.62	0.573	0.409	0.066	0.099	0.082- 0.118	13295.952
Two Factors 6 skills	11.259 (8)	1.40	0.971	0.945	0.028	0.033	0.000-0.074	9070.188

Note. a = acceptable fit value; g = good fit value; r = robust standard errors and a robust (scaled) test statistic; b = Sample-size adjusted BIC. *p-value < .01.

The skills factorial loadings of the final model with two domains and six motor skills presented an acceptable value (0.61) for the CR (Figure 1).

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

After testing the fittest model, a network analysis was conducted to explore the relationships between fundamental motor skills, sex, age and BMI in the final model (Figure 2). Results highlighted main relationships between sex and throwing (r = -. 22), and strike (r = -. 21), indicating better performance for the boys. Positive relationships were found between age with slide (r = 0.23) and hop (r = 0.28) and between BMI with throw (r = 0.18).

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

Positive relationships between the variables are expressed by the green color in the network and negative relationships by the red color. The thickness of the graph indicates the weight of the ratio. Results indicate throw and strike variables had the highest betweenness, closeness and strength indices, which are the variables that most influence the network configuration (Figure 3).

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

4. DISCUSSION

The present study is the first to show evidence of the validity and reliability of the internal structure of the TGMD-2 in Brazilian preschoolers of low-income sample. Such information is key for physical educators, public health professionals and those working with young children in understanding the best way to assess FMS. The results presented suggest that the original two-factor model of the TGMD-2 did not result in exact fit, and the constructs of locomotor and object control skills load on only 6 of the 12 skills identified in the TGMD-2.

The final model with six skills presented excellent model fit index values. These results are in agreement with validations of the long version of TGMD-2 (Farrokhi, Zareh Zadeh, Karimi Alvar, Kzaemnejad, & Ilbeigi, 2014; Kim et al., 2014; N. C. Valentini, 2012; Wong & Yin Cheung, 2010) and also with validations that resulted in reduction of TGMD-2 skills in adolescents (Issartel et al., 2017) and Brazilian children (Valentini et al., 2018). Our results showed the loading of 6 skills (gallop, hop and slide for the locomotor skills; and strike, throw and roll, for object control) range from .67 to .88. The lowest value belongs to hop and the highest one to roll. As the loading values below .30 are considered low, the values shown are quite desirable.

The results of the CFA originated a short version of TGMD-2, the running, leaping, horizontal jumping, bouncing, catching and kicking skills did not present adequate factor loads and were therefore excluded from the final model. While we recognize these skills are important in sports and physical activity, we suggest that not all motor skills are as fundamental and discriminating in assessing competence in FMS.

This perspective is theoretically congruent with recent research from Barnett et al., (2016), for example, suggesting motor assessment batteries should consider which motor skills are actually related to sports and physical activity according to context / culture and time for execution. This view is acceptable, but it requires a statistical interpretation. In the context of our study, soccer is a culturally common sport, so kicking ability in our sample had a mean value close to the possible maximum value (m = 6.15+ 1.49). However, in psychometric terms, it is possible that this ability does not discriminate the construct (ball skills), because children demonstrate similar performance with little variability, losing the power to differentiate children by different performance levels. This hypothesis is confirmed when looking at the value of the factorial load in the nine-skill alternative model (kick = 0.238). From a developmental view, one expects typically developed children of three to five years of age to better perform locomotor skills as run or jump, then skills as slide. Similarly, object control skills like kicking are culturally common for very young SES preschool children. Proficiency in kicking, jumping or running is expected in low SES settings, particularly in vulnerable zones where sports facilities are scarce and these skills are widely played outside. A systematic review and meta-analysis study supports the assertion that participation in specific leisure-time physical activities differs according to age and/or geographic region (Hulteen et al., 2017), in a way that geographic characteristics may determine which skills are developed (Hulteen et al., 2018).

Moreover, we may hypothesize that the remaining skills have similar characteristics to kicking or the excluded skills did not correlate sufficiently with the most discriminating skills. Consequently, it is possible that certain skills require less instruction and are obtainable through adequate levels of physical activity and unstructured play (Tomaz et al., 2019). Though the TGMD-2 is a widely used to assess proficiency in FMS worldwide, one of the key limitations of the measure is the time taken to conduct the assessment in the appropriate manner, as specified by Ulrich (2000). The current study suggests that, for low SES preschool children, it may be possible to gain an overall assessment of locomotor and object control skills in the TGMD-2 using fewer individual skills. This could be very attractive to researchers and professionals who work with child care, as they provide a more time-efficient tool (15min for short version vs. 45min for the entire protocol) and less labor-intensive means to assess FMS in preschoolers.

Even considering the latest version of the TGMD, the TGMD-3 excluded the roll skill, after CFA analysis, the roll skill presented adequate factor load and remained in our short version of TGMD-2. Considering roll is not a prevalent skill in the evaluated context in the current study, we may hypothesize that children present greater variability in its performance, which increases the power to differentiate their performance levels in relation to overall motor competence. From the findings of the current study it could be implied that the TGMD-3 should have kept the roll within the different skills it assesses. However, in the context of the present study it may be the roll is a relatively novel skill in Brazilian children and thus may better differentiate overall good and poor motor competence to a different extent than in other populations. So, the adoption of criteria related to the cultural importance of the skills in each country needs to be addressed, as current studies suggest. Moreover, other statistical techniques, besides CFA, can be useful in determining how essential these skills are, as the Item Response Theory (Carlson & von Davier, 2017), and network centrality measures.

It is also important to highlight that the present study showed psychometric properties for a short version of TGMD-2, which does not minimize the need for further studies that consider the standardization of the long and short versions of TGMD-2 and TGMD3, which would be useful for teachers to promote their interventions and also for the comparison of FMS in different countries.

Our results from the networking analysis emphasized strong positive associations between age and slide and hop skills. Even considering there are sensitive periods when the impact of age on FMS is stronger, this should be interpreted with caution, since this impact differs according to the target skill (Clark & Metcalfe, 2002) and not only according to its specific domain (locomotion or object control). Although age has been reported as a positive predictor of motor skills of locomotion and object control (Barnett et al., 2016), there are still few studies supporting this evidence in the range of 3 to 5 years old (Robinson et al., 2015). Moreover, the impact of age should always be considered according to the practice context (Clark & Metcalfe, 2002; Gabbard, 2011).

Likewise, a weak but negative association was seen for the relationship between BMI and locomotion skills of gallop and slide. Although reviews on the relationship between weight status and FMS shows there is an inverse relationship between those variables, and individuals with an unhealthy weight status tend to have poorer FMS than their healthy weight peers (Cattuzzo et al., 2016; Robinson et al., 2015) our results showed a moderate positive association between BMI and throw, reinforcing the idea that those associations are individual and environmental-dependent. We may hypothesize that the ability to locomote the body on space is weight status-dependent, while those abilities of pushing an object on the space may be enabled by a more corpulent body. Furthermore, a recent current opinion study highlights a conceptual model in which Hulteen et al., (2018) recognize the potential cultural and geographic specificity of motor skills, and that attributes such as weight status affect lifespan motor skill development. This reinforces the need for researchers and practitioners to establish the validity of their motor competence assessments specifically to the cultural context in which they take place.

Negative strong associations were seen between sex and strike and throw, being the girls less likely to better perform these skills. A systematic review with meta-analysis indicated that the influence of sex on locomotor and object control motor skills is inconclusive, particularly among young children Some studies reported boys perform better on FMS, especially on object control ones (L. M. Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Livonen & Sääkslahti, 2014), while other studies indicated that sex is not related to motor skills (Barnett et al., 2013). In the best scenario, boys and girls should always be encouraged to be physically active and to participate in sports activities at school and in other contexts, even knowing that boys can be more culturally encouraged (Evans, 2014; Garcia, 1994). Moreover, from a network perspective, it is expected that sex as variable would not connect to FMS. Such a finding may be indicative that there are equal conditions of practice for both boys and girls, specially at this age group.

In the present study, throw and strike have emerged as the variables with the highest centrality indicators, which reflects the role of these two skills in the emerging pattern of the network. The strength indicator is important to understand which variables present the strongest connections in the current network pattern. A variable with a high closeness value will be quickly affected by changes in any part of the network and may also affect other parts. Variables with higher betweenness values are more sensitive to changes and may act as a hub, connecting other pairs of variables. Throw and strike are unusual skills for children in the evaluated context, with a greater degree of complexity, as it requires strength, speed, balance, and synchronized movements of legs, trunk and arms. We may hypothesize that children present greater variability in its performance, that varies according to age, sex and BMI, which increases the power of these skills to differentiate their performance levels in relation to overall motor skills. While we recognize the other skills are important in sports and daily PA, the network analysis suggests that each FMS has a different discriminating role in the entire system.

In this respect, a short version of TGMD-2 represents an important development for motor competence researchers. This is because it reduces administration time whilst still providing a robust measure of motor competence for teachers´ physical educationalists, and health professionals. The current study demonstrates the potential for a short version of TGMD-2 to be used in schools and other similar settings. However, standardized scores and normative reference values are not yet available for the short version. Following from the current study, establishing normative reference data is an important next step that would aid with pragmatic use of the TGMD-2 short version for practitioners.

5. CONCLUSIONS

The present study, for the first time, highlights the validity of TGMD-2 in low income preschoolers. This is a fundamental step in establishing the usefulness of this measure for the population concerned. The results of the present study, based on confirmatory factor analysis, suggest a short version of TGMD-2 for children with low SES, which is useful for teachers and researchers to optimize motor assessment and future interventions quickly and effectively.

The present study also used a machine learning approach via network analysis to associate FMS with gender, age and BMI in children from 3 to 5 years. This perspective considers that all variables are connected and are responsible for positive health trajectories throughout childhood and adolescence. Moreover, the present study presents a new insight from the centrality indices to promote health through motor and sports interventions.

6. ACKNOWLEDGMENTS AND FUNDING

Martins C. was supported by Brazilian Federal Foundation for Support and Evaluation of Graduate Education - CAPES (CAPES-PRINT - 88887.369625/2019-00). Mota J. was supported by grants: FCT: SFRH/BSAB/142983/2018 and UID/DTP/00617/2019.

7. AUTHORS' CONTRIBUTIONS

PFRB conceived and designed the analysis, performed the analysis and wrote the paper; MD conceived and designed the analysis and wrote the paper; MLFP collect the data, wrote the paper and submitted the paper; LNS collect the data, contributed data or analysis tools; IAAS contributed data or analysis tools; JM wrote the paper; CMLM conceived and designed the analysis, performed the analysis, collect the data and wrote the paper.

8. COMPETING INTERESTS

The authors declare that they have no competing interests.

9. REFERÊNCIAS

Asparouhov, Tihomir, & Muthén, Bengt. (2009). Exploratory Structural Equation Modeling. *Structural Equation Modeling: A Multidisciplinary Journal, 16*(3), 397-438. doi:10.1080/10705510903008204

Association, World Medical. (2013). World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *Journal of the American Medical Association, 310*(20), 2191-2194. doi:10.1001/jama.2013.281053

Bagozzi, Richard P., & Yi, Youjae. (1988). On the evaluation of structural equation models. *Journal of the Academy of Marketing Science, 16*(1), 74-94. doi:10.1007/BF02723327

Barnett, L., Hinkley, T., Okely, A. , & Salmon, J. (2013). Child, family and environmental correlates of children's motor skill proficiency. *Journal of Science and Medicine in Sport, 16*(4), 332-336. doi:10.1016/j.jsams.2012.08.011

Barnett, L. M., Lai, S. K., Veldman, S. L. C., Hardy, L. L., Cliff, D. P., Morgan, P. J., . . . Okely, A. D. (2016). Correlates of Gross Motor Competence in Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Medicine, 46*(11), 1663-1688. doi:10.1007/s40279-016-0495-z

Barnett, L. M., van Beurden, E., Morgan, P. J., Brooks, L. O., & Beard, J. R. (2010). Gender differences in motor skill proficiency from childhood to adolescence: a longitudinal study. *Research Quarterly for Exercise and Sport, 81*(2), 162-170. doi:10.1080/02701367.2010.10599663

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*(2), 238-246. doi:10.1037/0033-2909.107.2.238

Brian, A., Pennell, A., Taunton, S., Starrett, A., Howard-Shaughnessy, C., Goodway, J. D., . . . Stodden, D. (2019). Motor Competence Levels and Developmental Delay in Early Childhood: A Multicenter Cross-Sectional Study Conducted in the USA. *Sports Medicine, 49*(10), 1609-1618. doi:10.1007/s40279-019-01150-5

Byrne, Barbara M. (2013). *Structural equation modeling with Mplus: Basic concepts, applications, and programming*: routledge.

Carlson, James E., & von Davier, Matthias. (2017). Item Response Theory. In Randy E. Bennett & Matthias von Davier (Eds.), *Advancing Human Assessment: The Methodological, Psychological and Policy Contributions of ETS* (pp. 133-178). Cham: Springer International Publishing.

Cattuzzo, M. T., Dos Santos Henrique, R., Re, A. H., de Oliveira, I. S., Melo, B. M., de Sousa Moura, M., . . . Stodden, D. (2016). Motor competence and health related physical fitness in youth: A systematic review. *Journal of Science and Medicine in Sport, 19*(2), 123-129. doi:10.1016/j.jsams.2014.12.004

Chow, B. C., & Louie, L. H. (2013). Difference in children's gross motor skills between two types of preschools. *Perceptual and Motor Skills, 116*(1), 253-261. doi:10.2466/25.06.10.Pms.116.1.253-261

Clark, Jane E, & Metcalfe, Jason S. (2002). The mountain of motor development: A metaphor. *Motor development: Research and reviews, 2*(163-190), 183-202.

Cohen, Jacob. (2013). Statistical Power Analysis for the Behavioral Sciences.

Epskamp, Sacha, Cramer, Angélique OJ, Waldorp, Lourens J, Schmittmann, Verena D, & Borsboom, Denny. (2012). qgraph: Network visualizations of relationships in psychometric data. *Journal of Statistical Software, 48*(4), 1-18.

Farrokhi, A, Zareh Zadeh, M, Karimi Alvar, L, Kzaemnejad, A, & Ilbeigi, S. (2014). Reliability and validity of test of gross motor development-2 (Ulrich, 2000) among 3-10 aged children of Tehran City. *Journal of Physical Education and Sports Management, 5*(2), 18-28.

Fornell, Claes, & Larcker, David F. (1981). Structural Equation Models with Unobservable Variables and Measurement Error: Algebra and Statistics. *Journal of Marketing Research, 18*(3), 382-388. doi:10.2307/3150980

Foygel, Rina, & Drton, Mathias. (2010). *Extended Bayesian information criteria for Gaussian graphical models.* Paper presented at the Advances in neural information processing systems.

Friedman, Jerome, Hastie, Trevor, & Tibshirani, Robert. (2007). Sparse inverse covariance estimation with the graphical lasso. *Biostatistics, 9*(3), 432-441. doi:10.1093/biostatistics/kxm045

Fruchterman, Thomas M. J., & Reingold, Edward M. (1991). Graph drawing by force-directed placement. *Software: Practice and Experience, 21*(11), 1129-1164. doi:10.1002/spe.4380211102

Gabbard, CP. (2011). Lifelong motor development: Pearson Higher Ed.

Goodway, Jacqueline D, Ozmun, John C, & Gallahue, David L. (2019). *Understanding motor development: Infants, children, adolescents, adults*: Jones & Bartlett Learning.

Hair, JF, Black, WC, Babin, BJ, Anderson, RE, & Tatham, RL. (2009). Análise multivariada de dados: Bookman Editora.

Hardy, L. L., King, L., Farrell, L., Macniven, R., & Howlett, S. (2010). Fundamental movement skills among Australian preschool children. *Journal of Science and Medicine in Sport, 13*(5), 503-508. doi:10.1016/j.jsams.2009.05.010

Hu, Li-tze, & Bentler, Peter M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1-55. doi:10.1080/10705519909540118

Hulteen, R. M., Morgan, P. J., Barnett, L. M., Stodden, D. F., & Lubans, D. R. (2018). Development of Foundational Movement Skills: A Conceptual Model for Physical Activity Across the Lifespan. *Sports Medicine, 48*(7), 1533-1540. doi:10.1007/s40279-018-0892-6

Hulteen, R. M., Smith, J. J., Morgan, P. J., Barnett, L. M., Hallal, P. C., Colyvas, K., & Lubans, D. R. (2017). Global participation in sport and leisure-time physical activities: A systematic review and meta-analysis. *Preventine Medicine, 95,* 14-25. doi:10.1016/j.ypmed.2016.11.027

Issartel, J., McGrane, B., Fletcher, R., O'Brien, W., Powell, D., & Belton, S. (2017). A cross-validation study of the TGMD-2: The case of an adolescent population. *Journal of Science and Medicine in Sport, 20*(5), 475-479. doi:10.1016/j.jsams.2016.09.013

Jöreskog, Karl G, & Sörbom, Dag. (1981). *LISREL 5: analysis of linear structural relationships by maximum likelihood and least squares methods;[user's guide]*: University of Uppsala.

Kim, S., Kim, M. J., Valentini, N. C., & Clark, J. E. (2014). Validity and reliability of the TGMD-2 for South Korean children. *Journal of Motor Behavior, 46*(5), 351-356. doi:10.1080/00222895.2014.914886

Klingberg, B., Schranz, N., Barnett, L. M., Booth, V., & Ferrar, K. (2019). The feasibility of fundamental movement skill assessments for pre-school aged children. *Journal of Sports Sciences, 37*(4), 378-386. doi:10.1080/02640414.2018.1504603

Livonen, S., & Sääkslahti, A. K. (2014). Preschool children's fundamental motor skills: a review of significant determinants. *Early Child Development and Care, 184*(7), 1107-1126. doi:10.1080/03004430.2013.837897

Lopes, Vítor P., Saraiva, Linda, & Rodrigues, Luis P. (2018). Reliability and construct validity of the test of gross motor development-2 in Portuguese children. *International Journal of Sport and Exercise Psychology, 16*(3), 250-260. doi:10.1080/1612197X.2016.1226923

Marôco, J. (2010). Análise de equações estruturais: Fundamentos teóricos, software e aplicação.

McPhillips, M., & Jordan-Black, J. A. (2007). The effect of social disadvantage on motor development in young children: a comparative study. *Journal of Child Psychology and Psychiatry, 48*(12), 1214-1222. doi:10.1111/j.1469-7610.2007.01814.x

Morley, D., Till, K., Ogilvie, P., & Turner, G. (2015). Influences of gender and socioeconomic status on the motor proficiency of children in the UK. *Human Movement Science, 44,* 150-156. doi:10.1016/j.humov.2015.08.022

Nobre, Francisco Salviano Sales, Bandeira, Paulo Felipe Ribeiro, & Valentini, Nadia Cristina. (2016). Motor delays in socioeconomically disadvantaged children: a Bioecological look/Atrasos motores em criancas desfavorecidas socioeconomicamente. Um olhar Bioecologico. *Motricidade, 12*(2), 59-70.

Nobre, Francisco Salviano Sales, Coutinho, Mônia Tainá Cambruzzi, & Valentini, Nadia Cristina. (2014). The ecology of motor development in coastal school children of Brazil northeast. *Journal of Human Growth and Development, 24*(3), 263-273.

Nobre, Francisco Salviano Sales, Valentini, Nadia Cristina, & Rusidill, Mary Elizabeth. (2020). Applying the bioecological theory to the study of fundamental motor skills. *Physical Education and Sport Pedagogy, 25*(1), 29-48. doi:10.1080/17408989.2019.1688772

Piek, J. P., Baynam, G. B., & Barrett, N. C. (2006). The relationship between fine and gross motor ability, self-perceptions and self-worth in children and adolescents. *Human Movement Science, 25*(1), 65-75. doi:10.1016/j.humov.2005.10.011

Raykov, Tenko. (2001). Bias of Coefficient afor Fixed Congeneric Measures with Correlated Errors. *Applied Psychological Measurement, 25*(1), 69-76. doi:10.1177/01466216010251005

Reeves, L., Broeder, C. E., Kennedy-Honeycutt, L., East, C., & Matney, L. (1999). Relationship of fitness and gross motor skills for five- to six-yr.-old children. *Perceptual and Motor Skills, 89*(3 Pt 1), 739-747. doi:10.2466/pms.1999.89.3.739

Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., & D'Hondt, E. (2015). Motor Competence and its Effect on Positive Developmental Trajectories of Health. *Sports Medicine, 45*(9), 1273-1284. doi:10.1007/s40279-015-0351-6

Schwarz, Gideon. (1978). Estimating the Dimension of a Model. *The Annals of Statistics, 6*(2), 461-464.

Steiger, James H. (1990). Structural Model Evaluation and Modification: An Interval Estimation Approach. *Multivariate Behavioral Research, 25*(2), 173-180. doi:10.1207/s15327906mbr2502_4

Stodden, David F., Goodway, Jacqueline D., Langendorfer, Stephen J., Roberton, Mary Ann, Rudisill, Mary E., Garcia, Clersida, & Garcia, Luis E. (2008). A Developmental Perspective on the Role of Motor Skill Competence in Physical Activity: An Emergent Relationship. *Quest, 60*(2), 290-306. doi:10.1080/00336297.2008.10483582

Tamplain, Priscila, Webster, E. Kipling, Brian, Ali, & Valentini, Nadia C. (2019). Assessment of Motor Development in Childhood: Contemporary Issues, Considerations, and Future Directions. 1. doi:10.1123/jmld.2018-0028

Tomaz, S. A., Jones, R. A., Hinkley, T., Bernstein, S. L., Twine, R., Kahn, K., . . . Draper, C. E. (2019). Gross motor skills of South African preschool-aged children across different income settings. *Journal of Science and Medicine in Sport, 22*(6), 689-694. doi:10.1016/j.jsams.2018.12.009

Tucker, Ledyard R., & Lewis, Charles. (1973). A reliability coefficient for maximum likelihood factor analysis. *Psychometrika, 38*(1), 1-10. doi:10.1007/BF02291170

Ulrich, DA. (2000). Test of Gross Motor Development Examiner’s Manual. In: Austin, Texas: Pro Ed.

Valentini, Felipe, & Damásio, Bruno Figueiredo. (2016). Variância Média Extraída e Confiabilidade Composta: Indicadores de Precisão. *Psicologia: Teoria e Pesquisa, 32*.

Valentini, N. C. (2012). Validity and reliability of the TGMD-2 for Brazilian children. *Journal of Motor Behaviour, 44*(4), 275-280. doi:10.1080/00222895.2012.700967

Valentini, N. C., Rudisill, M. E., Bandeira, P. F. R., & Hastie, P. A. (2018). The development of a short form of the Test of Gross Motor Development-2 in Brazilian children: Validity and reliability. *Child Care Health Development, 44*(5), 759-765. doi:10.1111/cch.12598

Venetsanou, Fotini, & Kambas, Antonis. (2010). Environmental Factors Affecting Preschoolers’ Motor Development. *Early Childhood Education Journal, 37*(4), 319-327. doi:10.1007/s10643-009-0350-z

Wong, Ka Yee Allison, & Yin Cheung, Siu. (2010). Confirmatory Factor Analysis of the Test of Gross Motor Development-2. *Measurement in Physical Education and Exercise Science, 14*(3), 202-209. doi:10.1080/10913671003726968

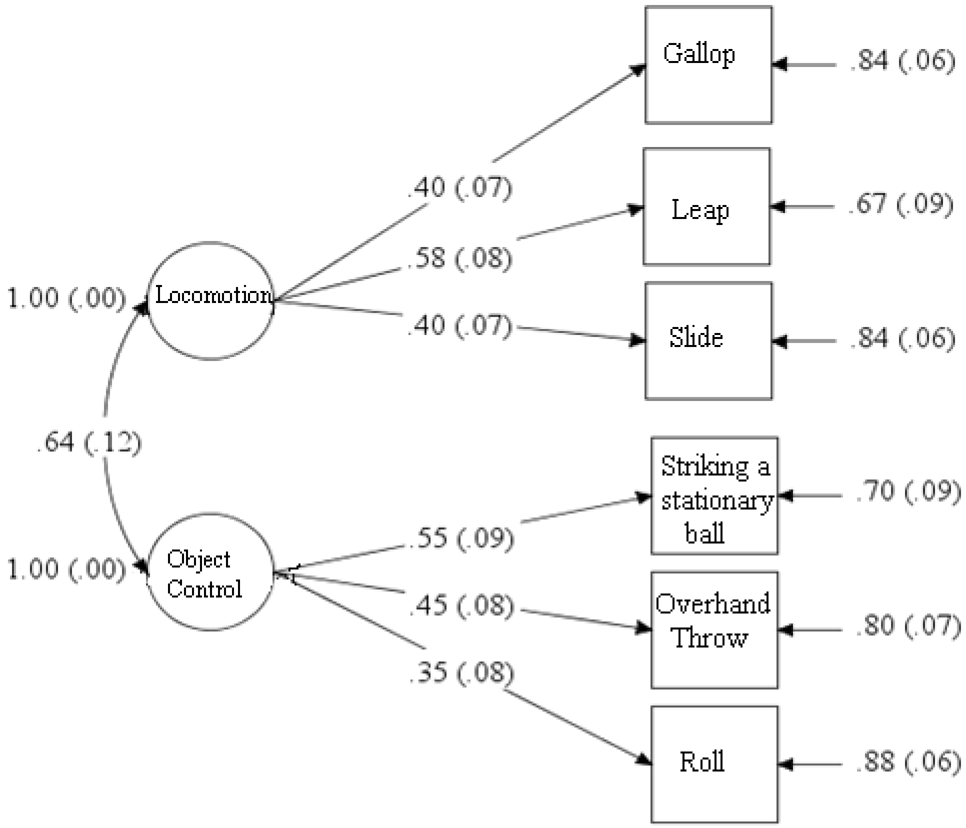

Figure 1. Final model with six skills

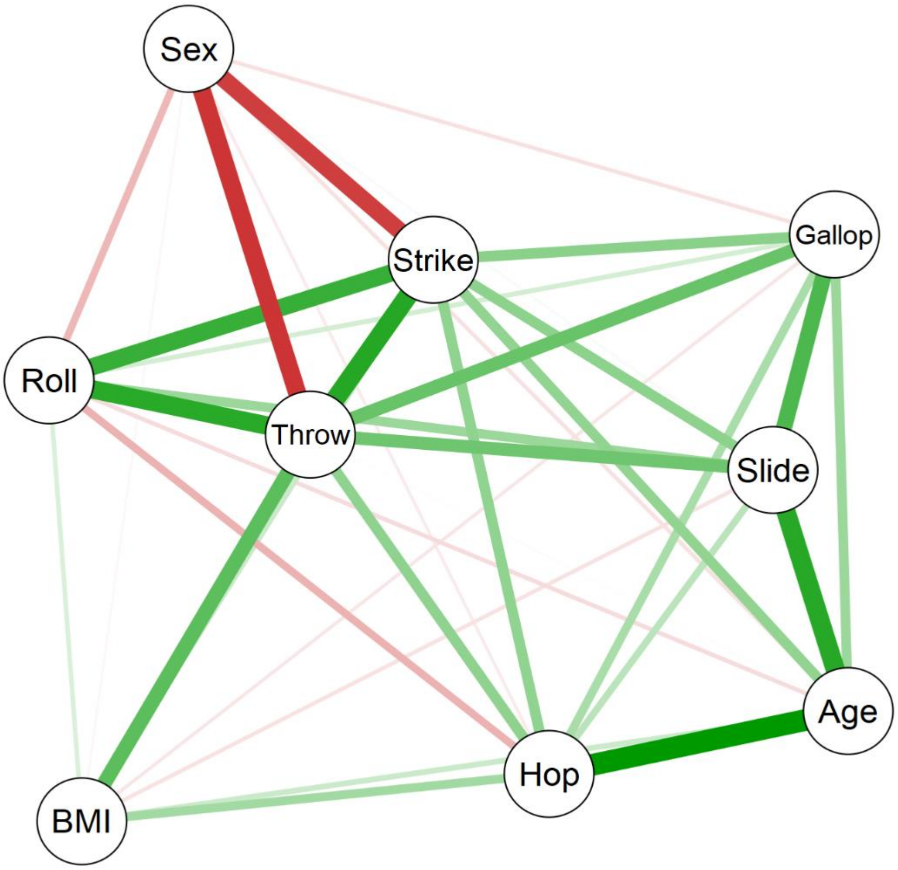

Figure 2. Associations between fundamental motor skills, sex, age and BMI. Positive relationships are expressed by the green color in the network and negative relations by the red color. The thickness of the graph indicates the weight of the ratio.

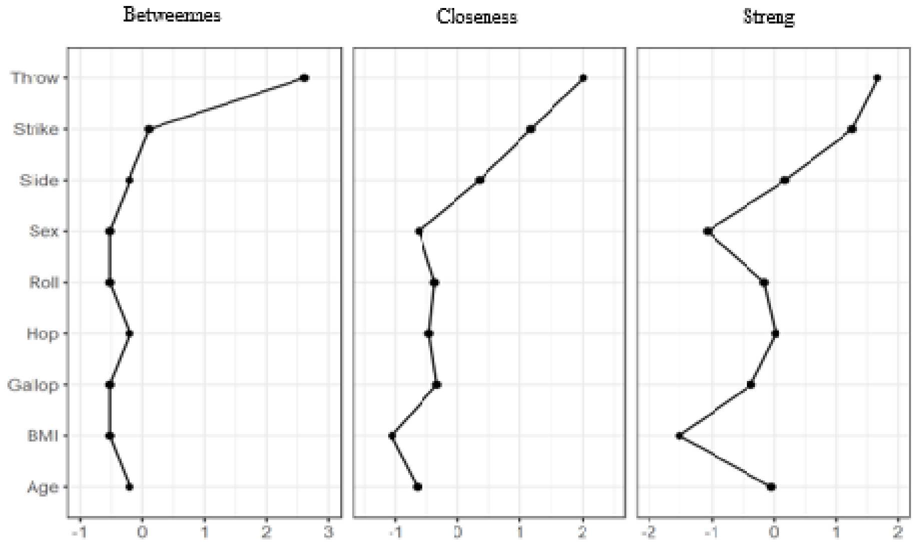

Figure 3. Graph representation of the centrality of the association between fundamental movement skills, sex, age and BMI.

Table 1. Sample´s characteristics

	Mean±SD			
	GIRLS (n=192)	BOYS (n=176)	Cohen´s *d*	TOTAL (n=368)
Age (years)	4.83±0.48	4.80±0.48		4.82±0.48
Weight (kg)	18.37±3.65	18.04±3.00	.03	18.21±3.35
Height (cm)	107.5±6.69	106.6±6.10	.14	107.1±6.42
BMI (kg/m²)	16.02±1.96	16.04±1.75	-.01	16.03±1.86
Locomotor				
Run	6.25±1.24	6.61±1.33*	-.28	6.42±1.29
Gallop	2.41±2.25	2.54±2.56	.38	2.47±2.40
Hop	3.18±2.12	3.25±1.97	-.03	3.22±2.05
Leap	3.82±1.72	4.30±1.73*	-.02	4.05±1.74
Jump	2.31±1.47	2.65±1.72*	-.21	2.48±1.60
Slide	1.88±2.34	1.85±2.07	-.01	1.87±2.21
Object control				
Strike	3.89±2.08	4.68±2.59*	-.34	4.27±2.37
Bounce	0.36±0.96	0.45±1.18	-.08	0.47±1.07
Catch	2.69±1.72	2.83±1.59	-.08	2.75±1.66
Kick	6.15±1.49	6.50±1.73*	-.22	6.31±1.62
Throw	0.47±1.06	0.84±1.44*	-.30	0.65±1.27
Roll	1.66±1.68	1.86±1.60	-.13	1.76±1.64
	Absolute frequency		Relative frequence	
State				
Paraíba	251		68.2	
Pernambuco	64		17.4	
Ceará	53		14.4	

*p<0,05 = Independent samples T Test

Table 2: Model´s adjustment indexes

Model	χ^2 (df)	χ^2/df	CFI	TLI	SRMR	RMSEA	90%CI RMSEA	BIC[b]
Robust method[r]								
Two Factor 12 skills	198.716 (53)*	3.74	0. 502	0.380	0.065	0.086	0. 074- 0.099	17223.837
Two Factors 9 skills	115.622 (25)*	4.62	0.573	0.409	0.066	0.099	0.082- 0.118	13295.952
Two Factors 6 skills	11.259 (8)	1.40	0.971	0.945	0.028	0.033	0.000-0.074	9070.188

Note. a = acceptable fit value; g = good fit value; r = robust standard errors and a robust (scaled) test statistic; b = Sample-size adjusted BIC. *p-value < .01.