

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

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

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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.

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1. INTRODUCTION

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

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

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

99 The Test of Gross Motor Development (TGMD-2) (Ulrich, 2000) is one of the most
100 frequently used assessments to evaluate process-oriented FMS during childhood and
101 adolescence (Klingberg et al., 2019), and involves a comprehensive battery of movement
102 skills comprising both locomotor, the skills used for the purpose of transporting the body
103 through space, and object-control skills, which involve giving force to object or receiving
104 force from objects. It can be used to identify children who are significantly behind their
105 peers in gross motor performance, to plan programs to improve skills in those children

106 showing delays, and to assess changes as a function of increasing age, experience,
107 instruction or intervention (Ulrich, 2000). Although a valid and reliable measure,
108 administering the TGMD-2 demands a considerable amount of time to administer and to
109 interpret (Barnett, Hinkley, Okely, & Salmon, 2013), specifically trained staff, and a
110 specific space is required for its assessment. These requirements often make it
111 logistically more difficult to administer in childcare and school settings, with recent
112 research suggesting the TGMD-2 may not be the most feasible choice in the context of
113 preschool settings and preschool staff (Tamplain, Webster, Brian, & Valentini, 2019; N.
114 C. Valentini, Rudisill, Bandeira, & Hastie, 2018). In this sense, a short version of the
115 TGMD-2 will reduce administration time, facilitate the screening of children with delays
116 in FMS, and may optimize the intervention process by teachers, technicians and
117 researchers.

118 In Brazil, preschools in low-income contexts differ markedly from those in high-
119 income environments in terms of the number of students per class, the available
120 infrastructure and the motivation of the teachers, aspects that may compromise
121 children's movement opportunities (Nobre, Coutinho, & Valentini, 2014). Likewise, low-
122 income children have different motor patterns when comparing to high-income ones
123 (Chow & Louie, 2013; McPhillips & Jordan-Black, 2007; Morley, Till, Ogilvie, & Turner,
124 2015; Venetsanou & Kambas, 2010). Although studies have already shown the
125 psychometric properties of the TGMD-2 full version for preschoolers (Kim, Kim, Valentini,
126 & Clark, 2014; Lopes, Saraiva, & Rodrigues, 2018; N. C. Valentini, 2012), FMS correlates
127 differ according to skill category and are context specific (Barnett et al., 2013). It is
128 therefore essential to assess how the TGMD-2 performs in different field-based contexts.
129 Though a previous study has proposed a TGMD-2 short version for Brazilian children,
130 data comprised children from early and later childhood (8.10 ± 1.32 years-old) and were
131 not low-income context-specific (Valentini et al., 2018).

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

138 Given the importance of FMS and its correlates for lifelong physical activity and
139 developmental outcomes in preschool-aged children, it is important to identify which
140 skills better represent the FMS's construct in respect to local characteristics of low-
141 income children in addition to how well they associate with different correlates. This study
142 aimed to address this issue by analyzing the internal structure and evidence of validity

143 and reliability of the TGMD-2 for a low-income sample of preschool children; and
144 investigate the possible associations between the final model proposed with sex, age
145 and BMI.

146

147 **2. METHODS**

148 *2.1 Study Description*

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

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

158

159 *2.2 Participants and settings*

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

163 For the purpose of this study, the deprived areas were characterized by zones
164 where employment, health, education, and social services are scarce, and where the
165 Human Development Index (HDI) range from 0.45 to 0.56. Of the 18 preschools originally
166 approached, 6 declined participation (4 because they did not feel comfortable with
167 research being conducted in their setting and 2 because they were compromised with
168 other projects being developed in the school). Participants were randomly selected from
169 12 preschools who agreed in participating (6 in Paraíba, 3 in Pernambuco and 3 in
170 Ceará).

171 The total sample comprised girls and boys who did not present differences for
172 age and for anthropometric variables [mean age = 4.82 ± 0.48 years, mean height =
173 107.10 ± 6.42 cm, median BMI = 15.9 (15.4; 16.8) kg/m^2 , and median z-BMI = 0.23 (-
174 0.13; 0.78) units], who lived in deprived areas and were from low SES families: 58.5% of
175 the mothers or fathers were unemployed and over 56% of the mothers and 44% of the
176 fathers had finished the 9th grade or less, and receive up to one minimum salary per
177 month.

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179

180 *2.3 Procedures*

181 Anthropometry measurements

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

188

189 Test of Gross Motor Development – TGMD-2

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

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

208

209 *2.4 Statistical procedures*

210 Descriptive analysis

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

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

217 Independent sample t-tests were conducted to compare anthropometric data and
218 fundamental motor skills according to sex. The effect size was calculated from cohen's
219 d, values <0.2 considered small, 0.2 <d <0.5 moderate, and d> 0.5 large (Cohen, 2013).

220

221 Confirmatory factorial analysis

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

226 To evaluate the quality of the adjustments of the models, we used the
227 Comparative Fit Index – CFI (Bentler, 1990) the Tucker-Lewis Index – TLI (Tucker &
228 Lewis, 1973), the mean square error of approximation – RMSEA (Steiger, 1990) and the
229 residual standardized mean square root – SRMR (Jöreskog & Sörbom, 1981). The
230 Bayesian information criteria – BIC (Schwarz, 1978) was considered for the evaluation
231 of alternative models. An adequate adjustment was considered when CFI and TLI values
232 were > 0.90, while values of > 0.95 indicated good fit (Bentler, 1990; Hu & Bentler, 1999).
233 RMSEA and SRMR values between 0.05 and 0.08 indicated acceptable fit, while values
234 <0.05 indicated good fit (Hu & Bentler, 1999). Models with lower Bayesian criteria values
235 indicated higher adjustment, when comparing to models with higher values (Byrne,
236 2013). Internal consistency was evaluated considering the composite reliability and the
237 Omega Coefficient (Raykov, 2001). The Mplus 8.0 and the Rstudio (free version) were
238 used for the analysis. The reliability analysis was calculated through Composite
239 Reliability (CR). The CR is an indicator of the structural quality of a psychometric
240 instrument (Fornell & Larcker, 1981; Hair, Black, Babin, Anderson, & Tatham, 2009). To
241 calculate the CR, the parameters estimated by the structural equations modeling of the
242 CFA are used. The CR values can be altered by the number of items in the dimension
243 and by the homogeneity of the factorial loadings, so the cut-off point for this indicator
244 may be questionable in dimensions with few items (F. Valentini & Damásio, 2016). An
245 acceptable value for CR is 0.60 (Bagozzi & Yi, 1988).

246

247 Network Analysis

248 The possible relationships between the basic motor skills of the final model
249 (gallop past, lateral running, striking, throwing over and roll) with age, sex and BMI were
250 calculated using a "Machine Learning" technique entitled network analysis, which aims

251 to establish relationships through multiple interactions between variables from graphical
 252 representations (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012).

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

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

271

272 **3. RESULTS:**

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

276

277 Table 1. Sample’s characteristics

| | Mean±SD | | | |
|-------------------------------|------------------|-----------------|---------------------|------------------|
| | GIRLS (n=192) | BOYS (n=176) | Cohen’s <i>d</i> | 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 frequency | |
| State | | | | |
| Paraíba | 251 | | | 68.2 |
| Pernambuco | 64 | | | 17.4 |
| Ceará | 53 | | | 14.4 |

*p<0,05 = Independent samples T Test

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281 *Step 1: Two-factors model with twelve skills*

282 In the original two-factor model (locomotion and object control) with 12 skills,
283 the general adjustment indexes were low. The factorial loadings of Run (0.127), Bounce
284 (0.256) and Kick (0.035) were low (<0.30), and the correlation between the locomotion
285 and object control factors was high (r = 0.718).

286

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

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

293

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

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

301

302 Table 2: Model's adjustment indexes

| Model | χ^2 (df) | χ^2/df f | CFI | TLI | SRMR | RMSEA | 90%CI RMSEA | BIC ^b |
|----------------------------|---------------|------------------|-------|-------|-------|-------|----------------|------------------|
| Robust method ^f | | | | | | | | |
| 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.

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304

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

307

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

309

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

316

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

318

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

324

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

326

327

328 **4. DISCUSSION**

329

330 The present study is the first to show evidence of the validity and reliability of the
331 internal structure of the TGMD-2 in Brazilian preschoolers of low-income sample. Such
332 information is key for physical educators, public health professionals and those working
333 with young children in understanding the best way to assess FMS. The results presented

334 suggest that the original two-factor model of the TGMD-2 did not result in exact fit, and
335 the constructs of locomotor and object control skills load on only 6 of the 12 skills
336 identified in the TGMD-2.

337 The final model with six skills presented excellent model fit index values. These
338 results are in agreement with validations of the long version of TGMD-2 (Farrokhi, Zareh
339 Zadeh, Karimi Alvar, Kzaemnejad, & Ilbeigi, 2014; Kim et al., 2014; N. C. Valentini, 2012;
340 Wong & Yin Cheung, 2010) and also with validations that resulted in reduction of TGMD-
341 2 skills in adolescents (Issartel et al., 2017) and Brazilian children (Valentini et al., 2018).
342 Our results showed the loading of 6 skills (gallop, hop and slide for the locomotor skills;
343 and strike, throw and roll, for object control) range from .67 to .88. The lowest value
344 belongs to hop and the highest one to roll. As the loading values below .30 are
345 considered low, the values shown are quite desirable.

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

351 This perspective is theoretically congruent with recent research from Barnett et
352 al., (2016), for example, suggesting motor assessment batteries should consider which
353 motor skills are actually related to sports and physical activity according to context /
354 culture and time for execution. This view is acceptable, but it requires a statistical
355 interpretation. In the context of our study, soccer is a culturally common sport, so kicking
356 ability in our sample had a mean value close to the possible maximum value ($m = 6.15 +$
357 1.49). However, in psychometric terms, it is possible that this ability does not discriminate
358 the construct (ball skills), because children demonstrate similar performance with little
359 variability, losing the power to differentiate children by different performance levels. This
360 hypothesis is confirmed when looking at the value of the factorial load in the nine-skill
361 alternative model (kick = 0.238). From a developmental view, one expects typically
362 developed children of three to five years of age to better perform locomotor skills as run
363 or jump, then skills as slide. Similarly, object control skills like kicking are culturally
364 common for very young SES preschool children. Proficiency in kicking, jumping or
365 running is expected in low SES settings, particularly in vulnerable zones where sports
366 facilities are scarce and these skills are widely played outside. A systematic review and
367 meta-analysis study supports the assertion that participation in specific leisure-time
368 physical activities differs according to age and/or geographic region (Hulteen et al.,
369 2017), in a way that geographic characteristics may determine which skills are developed
370 (Hulteen et al., 2018).

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

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

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

402 Our results from the networking analysis emphasized strong positive associations
403 between age and slide and hop skills. Even considering there are sensitive periods when
404 the impact of age on FMS is stronger, this should be interpreted with caution, since this
405 impact differs according to the target skill (Clark & Metcalfe, 2002) and not only according
406 to its specific domain (locomotion or object control). Although age has been reported as
407 a positive predictor of motor skills of locomotion and object control (Barnett et al., 2016),

408 there are still few studies supporting this evidence in the range of 3 to 5 years old
409 (Robinson et al., 2015). Moreover, the impact of age should always be considered
410 according to the practice context (Clark & Metcalfe, 2002; Gabbard, 2011).

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

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

439 In the present study, throw and strike have emerged as the variables with the
440 highest centrality indicators, which reflects the role of these two skills in the emerging
441 pattern of the network. The strength indicator is important to understand which variables
442 present the strongest connections in the current network pattern. A variable with a high
443 closeness value will be quickly affected by changes in any part of the network and may
444 also affect other parts. Variables with higher betweenness values are more sensitive to

445 changes and may act as a hub, connecting other pairs of variables. Throw and strike are
446 unusual skills for children in the evaluated context, with a greater degree of complexity,
447 as it requires strength, speed, balance, and synchronized movements of legs, trunk and
448 arms. We may hypothesize that children present greater variability in its performance,
449 that varies according to age, sex and BMI, which increases the power of these skills to
450 differentiate their performance levels in relation to overall motor skills. While we
451 recognize the other skills are important in sports and daily PA, the network analysis
452 suggests that each FMS has a different discriminating role in the entire system.

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

462

463 **5. CONCLUSIONS**

464

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

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

477

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483

484 **7. AUTHORS' CONTRIBUTIONS**

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

491

492 **8. COMPETING INTERESTS**

493 The authors declare that they have no competing interests.

494

495 **9. REFERÊNCIAS**

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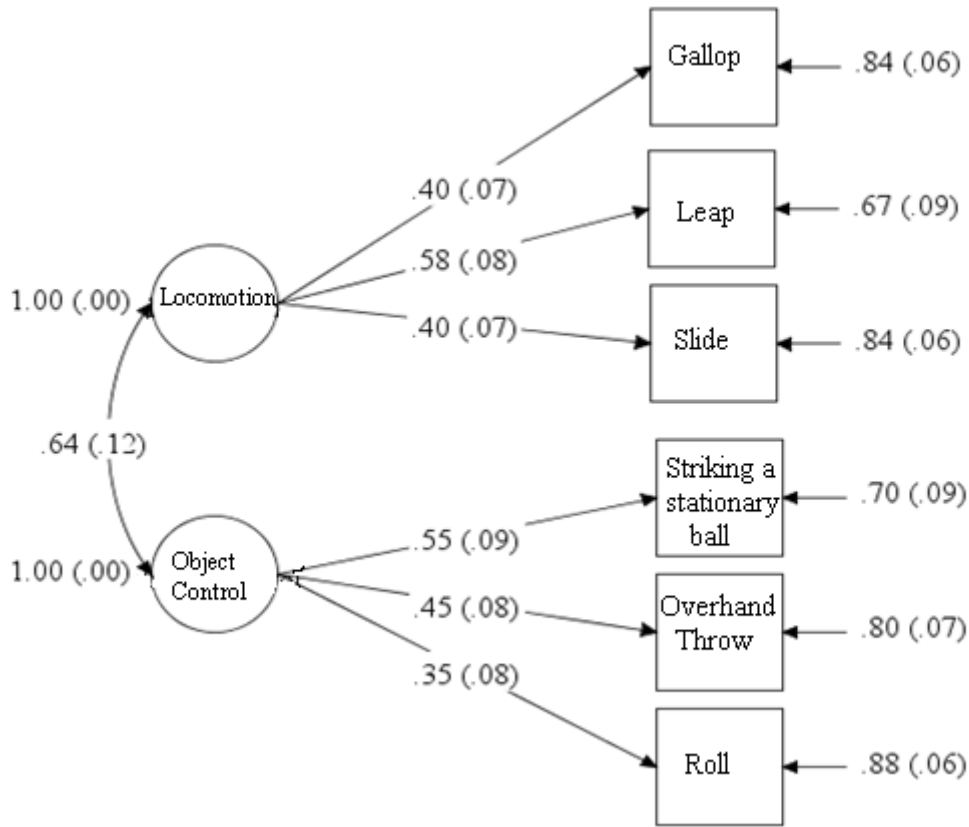
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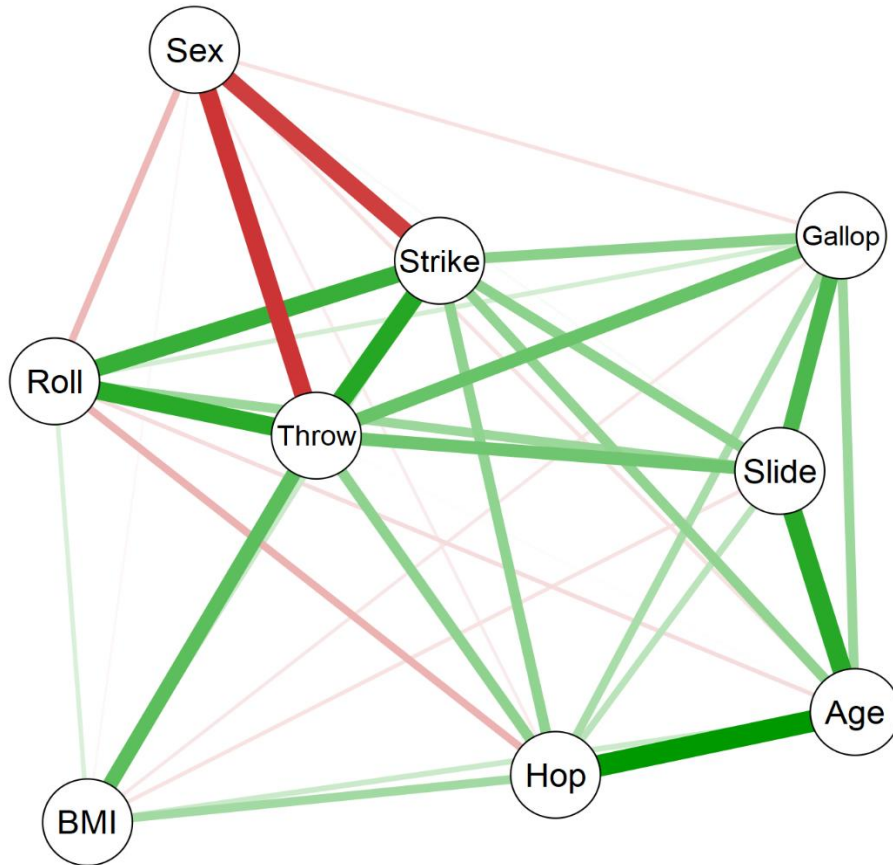
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 677 Figure 1. Final model with six skills

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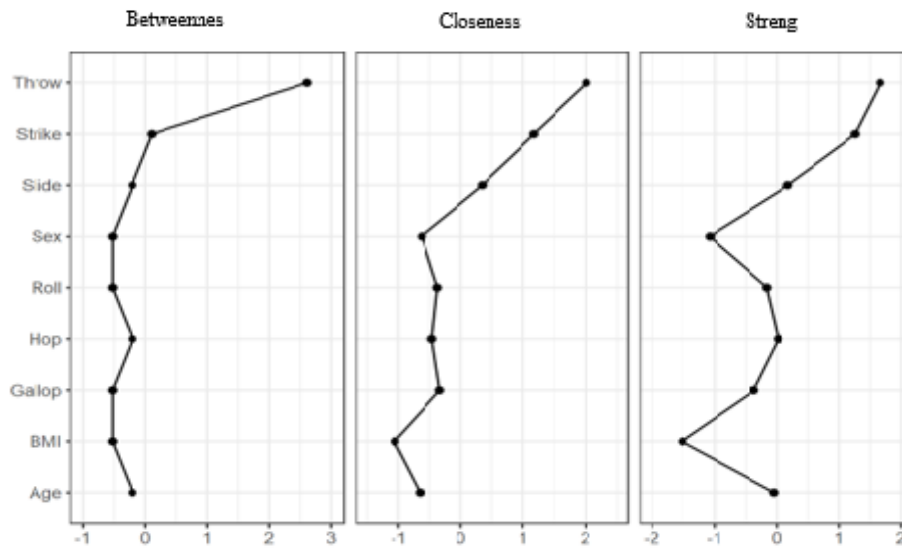
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696 Figure 2. Associations between fundamental motor skills, sex, age and BMI. Positive relationships
697 are expressed by the green color in the network and negative relations by the red color. The
698 thickness of the graph indicates the weight of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

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

718 Table 1. Sample's characteristics

| | Mean±SD | | | |
|-------------------------------|--------------------|-----------------|---------------------|------------------|
| | GIRLS (n=192) | BOYS (n=176) | Cohen's <i>d</i> | TOTAL (n=368) |
| Age (years) | 4.83±0.48 | 4.80±0.48 | | 4.82±0.48 |
| Weight (kg) | 18.37±3.6 | 18.04±3.00 | .03 | 18.21±3.35 |
| | 5 | | | |
| Height (cm) | 107.5±6.6 | 106.6±6.10 | .14 | 107.1±6.42 |
| | 9 | | | |
| BMI (kg/m²) | 16.02±1.9 | 16.04±1.75 | -.01 | 16.03±1.86 |
| | 6 | | | |
| 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 frequency | |
| State | | | | |
| Paraíba | 251 | | 68.2 | |
| Pernambuco | 64 | | 17.4 | |
| Ceará | 53 | | 14.4 | |

*p<0,05 = Independent samples T Test

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722 Table 2: Model's adjustment indexes

| Model | χ^2 (df) | $\frac{\chi^2}{df}$ | 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.

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