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PHYSICAL FITNESS IN 10-YEAR OLD CHILDREN: RELATIONSHIP BETWEEN ANTHROPOMETRIC MEASURES AND MOTOR ABILITIES

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ABSTRACT

The study aimed to comprehensively investigate associations between anthropometric features and motor abilities in young school-age children. The sample included 285 students (140 boys and 145 girls, aged 10.44 ± 0.33 years). Sex differences in the anthropometric and motor variables were determined by an independent t-test, while multiple linear regression was used to examine whether anthropometric characteristics could predict motor test scores. Girls were significantly taller, with greater sitting height, leg and arm length, as well as hip width. Also, greater body mass and skinfold thickness, as well as better scores on flexibility tests were observed in girls compared to boys ($t=1.384–3.290$, $p<0.05$). Conversely, boys demonstrated better scores on tests to evaluate coordination, agility, aerobic endurance, and strength. Except for movement frequency and flexibility, all motor items showed small-to-large correlations with anthropometric measures. Skinfold thickness, body mass index, arm girth, together with leg length and wrist diameter, explained 44% of the explosive strength variance, while 32% of aerobic endurance was explained by leg girth, BMI, and skinfold thickness. These results indicate that anthropometric measures have a significant influence on several motor abilities, especially explosive strength and aerobic endurance, while the role of anthropometry on flexibility, frequency of movement, and coordination seem to be negligible.

Key words: AEROBIC ENDURANCE / AGILITY / STRENGTH / BODY MASS INDEX / SKINFOLD THICKNESS

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INTRODUCTION

The movement represents one of the basic human needs that sustains life (Abernethy, Kippers, & Hanrahan, 2013). Physical activity is the foundation, not only of a healthy and positive way of spending free time but also of the biological integrity of modern man. It is well-documented that physical activity has a positive impact on overall health status, including both physical and mental well-being (Pelemiš et al., 2015). Any physical activity is determined by motor (or physical) abilities and, in general, motor abilities can be defined as genetically determined characteristics that influence movement performance and predominantly refer to dimensions such as coordination, flexibility, agility, and various types of strength and aerobic endurance (Bala & Popovic, 2007). Related to this is physical fitness, which besides the abovementioned motor abilities (i.e. performance-related fitness [PRF]), includes morphological features (anthropometric and body composition) (American College of Sports Medicine [ACSM], 2013). In children, physical fitness represents one of the most important health markers and should be considered an important predictor of future quality of life and sports participation (Battista et al., 2021). As such, monitoring physical fitness is highly important in physical education, since it provides necessary information about the overall health status of children.

The interrelationship between morphological and PRF in children has been well-documented. Among many morphological factors, measures of adiposity (BMI, skinfold thickness, fat percent, and mass) have shown to be the most important predictors of PRF in children (Pillsbury, Oria, & Pate, 2013). Specifically, BMI showed to negatively affect motor performance in children and adolescents, with correlation coefficient varying from small to moderate (Pelemiš et al., 2019; Fiori et al., 2020). Even greater association was observed for measures of body composition (i.e. skinfold thickness, fat mass and percent), where skinfold thickness and (or) fat mass might explain almost 70% of variance in strength, agility, speed and aerobic endurance (França et al., 2022). Also, a positive association was found between body height, free-fat mass, and various tests to evaluate speed, agility, and absolute and explosive strength (Katsikadelis & Đokić, 2020; Leão et al., 2022; Avcin et al., 2023). In fact, only flexibility and balance seem to be non-affected by morphological factors (D'Hondt, Deforche, De Bourdeaudhuij, & Lenoir, 2009; Katsikadelis & Đokić, 2020).

While the relationship between the abovementioned morphological measurements and PRF in children is well documented, there is scarce data regarding anthropometry-derived measurements of body segments, such as measurements of body length (leg length, sitting height, etc.) and measurements of body girth and diameter (leg girths, ankle diameter, foot diameter, knee diameter, and others). This is rather surprising considering that these measurements (particularly those affecting pelvic girdle biomechanics and lower leg inertial properties) significantly determine gait-related characteristics (Šentija, Rakovac, & Babić, 2012). Moreover, length, diameter and girth measures might be quite important for strength performance (Jaric, 2002). Therefore, the aim of the current study was to comprehensively investigate the association between PRF (coordination, flexibility, aerobic endurance and various types of strength) and anthropometric features (including measures of body length, girth, diameter, and skinfold thickness) in younger school-age (10-year-old) children. This specific, subject's age was selected, given that younger school age has been considered a "golden period for physical abilities" (Kurelić et al., 1975); i.e. this period has been characterized by the rapid development of almost all components of PRF.

METHOD

The sample consisted of 285 students (140 boys and 145 girls, aged 10.44 ± 0.33 years). This sample size was justified by a priori power analyses, using G-power software with a target correlation value (r) of 0.3, an alpha level of 0.05, and a power (1-ß) of 0.80 (Eng, 2003). All participants were healthy, without a history of musculoskeletal injuries or cardiovascular health issues. Also, participants and their parents were fully informed about experimental procedures and potential risks and signed a written informed consent prior to participation in the study. The study was approved by the Institutional Ethics Committee and conducted in accordance with the Declaration of Helsinki.

The experimental protocol consisted of two laboratory testing sessions; in the first session anthropometric status was evaluated, while on the second day, PRF (motor abilities) was assessed. Each session was performed in the morning hours (8-11 AM), with constant room temperature (20-25°). All subjects were familiarized with the motor tests during two pre-visits before data collection and were advised to avoid physical activity and solid food intake 2 hours before the testing.

The anthropometric assessment included longitudinal, circular, and transversal dimensions, as well as skinfold thickness, according to the recommendations of Westat (1988). Longitudinal variables were measured by portable Martin's anthropometer (Siber-Hegner, Switzerland), with 0.1 cm accuracy, and they included: body height, sitting height (distance between the sitting surface and the top of the head), leg length and arm length. Circular variables were taken by non-extensible 2-m measuring tape Harpenden (Holstein Ltd), with 0.1 cm accuracy, and they included upper arm and upper leg girth, and shoulder and hip width. Wrist diameter was taken as a transversal variable, using a cephalometer (GPM Instruments, Switzerland), with 0.1 cm accuracy. Biceps, triceps, subscapular, and abdomen skinfold thickness (ST) were determined using a Harpenden skinfold caliper (Harpenden, West Sussex, UK) according to procedures described by Eston & Reilly (2001). Briefly, subjects were in an upright position with their arm relaxed. For the biceps and triceps ST, the marked point was located in the mesobrachial region, while for the abdomen ST, the point was located 5 cm from the navel. For subscapular ST, the marked point was located below the left corner of the scapula. All ST acquisitions were performed on the left side of the body. Baseline and final measurements were performed by an experienced specialist in the morning hours (8-10 am) at constant room temperature (20-25°).

The test battery comprised a total of 8 items and was administered according to a standardized protocol (Bala & Popovic, 2007): for accessing frequency of movement – Hand taping (freq); for body flexibility assessing – Sit and reach (m); for assessing explosive power - Standing long jump (m); for assessing body coordination – Ball rejection (freq.); for assessing upper body strength endurance - Pull-up endurance (s); for assessing trunk strength - Sit-ups in 30 seconds (freq); for agility assessing - 10x5 meter test (s); for accessing aerobic endurance – Shuttle run test (s). All testing sessions were supervised by two experienced physical education teachers. Attention was paid to proper form throughout the testing.

The Shapiro–Wilks's test was used to test the normality of the distribution. A series of independent t-tests were used to determine the sex differences in the tested variables. Pearson's coefficient correlation was used to examine relations between motor and anthropometric variables. Qualitative interpretations of the r coefficients were defined such as 0.00–0.09 trivial; 0.10–0.29 small; 0.30–0.49 moderate; 0.50–0.69 large; 0.70–0.89 very large; 0.90–0.99 nearly perfect; 1.00 perfect (Hopkins, Marshall, Batterham, & Hanin, 2009). Further, the correlation coefficients were directly compared with their 95% confidence intervals. The backward multiple regression was applied to identify the best fit model, composed of the anthropometric variables, for the prediction of each motor test. Before regression analysis, multicollinearity was explored using a variance inflation factor (VIF), and each variable that had VIF 10 or higher, was excluded from the model. Statistical analysis was processed using the IBM SPSS Statistics software package (Version 21, SPSS Inc., Chicago, IL, USA). All data are presented by mean and standard deviation. $p \leq 0.05$ were taken as a statistically significant determinant.

RESULTS

Sex differences in tested variables

As expected, there were sex differences in anthropometric and motor variables. Compared to boys, girls were taller ($t = 3.290$, $p < 0.01$), with greater sitting height ($t = 3.500$, $p < 0.01$), leg ($t = 2.994$, $p < 0.01$) and arm ($t = 2.754$, $p < 0.01$) length, as well hip width ($t = 3.667$, $p < 0.01$). Also, greater body mass ($t = 2.150$, $p < 0.01$) and skinfold thickness ($t = 1.384 – 2.410$, $p < 0.05$), as well better scores on flexibility test ($t = 4.669$, $p < 0.01$) were observed in girls compared to boys. On the other hand, boys demonstrated significantly better scores on Standing long jump ($t = 2.902$, $p < 0.01$), Ball rejection ($t = 3.378$, $p < 0.01$), Pull-up endurance ($t = 3.236$, $p < 0.01$), 10 x 5 agility ($t = 4.210$, $p < 0.01$) and Shuttle run ($t = 5.298$, $p < 0.01$) test (Table 1).

Table 1. Sex-differences in anthropometric and motor variables

Variables	Boys	Girls	*p*
Body height (cm)	141.84 ± 7.01	144.75 ± 7.39	**0.001**
Body mass (kg)	35.94 ± 7.76	37.93 ± 7.18	**0.033**
BMI (kg/m^2)	17.72 ± 2.67	18.02 ± 2.65	0.363
Sitting height (cm)	74.09 ± 3.82	75.73 ± 3.81	**0.001**
Leg length (cm)	80.30 ± 4.68	82.10 ± 5.06	**0.003**
Arm length (cm)	58.76 ± 3.38	59.90 ± 3.36	**0.006**
Shoulder width (cm)	31.44 ± 1.95	31.57 ± 1.79	0.570
Hip width (cm)	23.98 ± 1.82	24.76 ± 1.6	**< 0.001**
Wrist diameter (cm)	4.58 ± 0.33	4.55 ± 0.32	0.494
Upper-arm girth (cm)	21.04 ± 2.76	21.49 ± 2.40	0.168
Upper-leg girth (cm)	29.46 ± 2.92	29.98 ± 2.84	0.145
Skinfold biceps (mm)	7.56 ± 3.32	8.56 ± 3.39	**0.017**
Skinfold triceps (mm)	13.08 ± 5.00	14.33 ± 4.66	**0.038**
Skinfold subscapular (mm)	9.38 ± 5.62	11.54 ± 6.93	**0.005**
Skinfold abdominal (mm)	13.13 ± 8.54	16.86 ± 9.44	**0.001**
Hand taping (freq)	15.56 ± 2.10	15.32 ± 1.63	0.296
Sit and reach (cm)	16.49 ± 5.70	19.90 ± 6.12	**< 0.001**
Standing long jump (cm)	149.70 ± 22.13	141.61 ± 23.16	**0.004**
Ball rejection (freq)	13.87 ± 3.69	12.40 ± 3.38	**0.001**
Sit ups (freq)	19.53 ± 5.29	18.49 ± 5.26	0.112
Pull-up endurance (s)	20.23 ± 18.02	13.62 ± 14.83	**0.001**
10 x 5 agility (s)	21.98 ± 1.99	22.99 ± 1.91	**< 0.001**
Shuttle run (s)	239.80 ± 102.85	179.71 ± 78.19	**< 0.001**

Relationship between anthropometric and motor variables

Except Hand Taping ($r = 0.015 - 0.105$, $p \geq 0.088$) and Sit and rich test ($r = 0.001 – 0.122$, $p \geq 0.054$), all motor test showed small-to-large correlations with anthropometric measures. Specifically, Standing long jump test showed strongest association with skinfold thickness ($r = 0.475 – 0.547$, $p < 0.01$), followed by BMI, arm and leg girth ($r = 0.254 – 0.450$, $p < 0.01$), as well body mass and wrist diameter ($r = 0.197 – 0.296$, $p < 0.05$). Pull-up endurance, Sit-ups, 10 x 5 agility and Shuttle run showed moderate-to-large correlations with skinfold thickness measures ($r = 0.352 – 0.556$, $p < 0.01$), and moderate correlations with BMI ($r = 0.307 – 0.471$, $p < 0.01$). Furthermore, Pull up endurance and Shuttle run were moderately associated with body mass and hip width ($r = 0.343 – 0.435$, $p < 0.01$). Arm girth and leg girth showed moderate correlation (r =

0.350 – 0.443, p < 0.01) with Shuttle run and Pull up endurance, and weak (r = 0.171 – 0.254, p < 0.05) or non-significant with other motor tests. Also, small correlations (r = 0.126 – 0.203, p < 0.05) were observed between Ball rejecting test with skinfold thickness, ankle diameter and sitting height (Tables 2 and 3).

Table 2. Relationship between motor tests and anthropometric measures

	Hand taping		Sit and rich		Long St Jump		Ball rejecting	
Variables	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Body height	-0.034	0.578	-0.048	0.439	0.076	0.216	0.141	0.022
Body mass	0.018	0.777	-0.066	0.285	-0.296	**0.000**	0.017	0.784
BMI	0.047	0.447	-0.056	0.368	-0.450	**0.000**	-0.068	0.270
Sitting height	-0.043	0.484	0.017	0.781	0.048	0.436	0.126	**0.042**
Leg length	-0.078	0.205	-0.064	0.299	0.130	**0.034**	0.181	0.003
Arm length	0.006	0.920	-0.026	0.672	0.120	0.051	0.138	0.025
Shoulder width	-0.035	0.572	0.001	0.998	0.075	0.222	0.129	**0.037**
Hip width	-0.023	0.711	0.011	0.861	-0.201	**0.001**	-0.001	0.983
Wrist diameter	-0.088	0.152	0.035	0.571	0.197	**0.001**	0.203	**0.001**
Upper-arm girth	0.026	0.674	-0.053	0.389	-0.352	**0.000**	-0.007	0.905
Upper-leg girth	-0.029	0.643	-0.082	0.186	-0.254	**0.000**	-0.004	0.950
Skinfold biceps	0.036	0.558	-0.115	0.061	-0.525	**0.000**	-0.173	**0.005**
Skinfold triceps	0.030	0.623	-0.122	0.054	-0.547	**0.000**	-0.196	**0.001**
Skinfold subscapular	0.015	0.815	-0.059	0.343	-0.475	**0.000**	-0.078	0.206
Skinfold abdominal	0.105	0.088	-0.081	0.191	-0.522	**0.000**	-0.155	**0.012**

Table 3. Relationship between motor tests and anthropometric measures

	Sit ups		**Pull up end**		**10 x 5 agility**		**Shuttle run**	
Variables	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Body height	-0.054	0.380	-0.220	**0.000**	-0.019	0.759	-0.092	0.138
Body mass	-0.243	**0.000**	-0.435	**0.000**	0.242	**0.000**	-0.388	**0.000**
BMI	-0.307	**0.000**	-0.450	**0.000**	0.343	**0.000**	-0.471	**0.000**
Sitting height	-0.089	0.147	-0.222	**0.000**	0.017	0.787	-0.140	0.023
Leg length	-0.014	0.820	-0.153	**0.013**	-0.077	0.215	-0.009	0.888
Arm length	0.048	0.433	-0.192	**0.002**	-0.072	0.245	-0.074	0.230
Shoulder width	-0.052	0.397	-0.193	**0.002**	-0.023	0.707	0.113	0.066
Hip width	-0.210	**0.001**	-0.383	**0.000**	0.167	**0.006**	-0.344	**0.000**
Wrist diameter	0.055	0.371	-0.010	0.876	-0.158	0.010	0.077	0.215
Upper-arm girth	-0.200	**0.001**	-0.409	**0.000**	0.253	**0.000**	0.433	**0.000**
Upper-leg girth	-0.171	**0.005**	-0.382	**0.000**	0.198	**0.000**	-0.350	**0.000**
Skinfold biceps	-0.352	**0.000**	-0.476	**0.000**	0.418	**0.000**	-0.523	**0.000**
Skinfold triceps	-0.345	**0.000**	-0.487	**0.000**	0.468	**0.000**	-0.556	**0.000**
Skinfold subscapular	-0.341	**0.000**	-0.375	**0.000**	0.361	**0.000**	-0.418	**0.000**
Skinfold abdominal	-0.405	**0.000**	-0.457	**0.000**	0.415	**0.000**	-0.485	**0.000**

Since Hand Taping and Sit and rich did not show significant correlations with anthropometric measures, they were excluded from further regression analysis. For the Long Standing Jump test, the best-fitting model included 6 variables: leg length, wrist diameter, upper-arm girth, as well biceps, triceps and abdominal skinfold thickness, which explained about 42% (F = 31.256, p < 0.001) of Long Standing Jump variance, with the equation for the model: y = 0.76 leg length + 8.36 wrist diameter + 1.76 upper-arm girth – 1.23 biceps skinfold – 1.44 triceps skinfold – 0.89 abdominal skinfold + 51.16. For the Ball rejecting test, the best-fitting model included two variables: wrist diameter and triceps skinfold, and explained about 8% (F = 12.316, p < 0.001) of motor test variance, with the equation: y = 2.44 wrist diameter – 0.16 triceps skinfold + 4.09 (Figure 1b). For the Sit-ups test, the best-fitting model included three variables: upper-arm girth, biceps and abdominal skinfolds, which explained about 22% (F = 25.651, p < 0.001) of motor test variance, with the equation: y = 0.92 upper-arm girth – 0.43 biceps skinfold – 0.31 abdominal skinfold + 7.582 (Figure 1c). For the Pull-up endurance test, the best-fitting model included five variables: BMI, arm length, upper-arm girth, as well biceps and triceps skinfolds, which explained about 27% (F = 19.105, p < 0.001) of motor test variance, with the equation: y = -2.29 BMI – 0.82 arm length + 2.50 upper-arm girth – 1.07 biceps skinfold - 1.200 triceps skinfold + 78.56 (Figure 1d). For the 10 x 5 agility test, the best-fitting model included three variables: upper-arm girth, and triceps and abdominal skinfolds, which explained about 28% (F = 33.788, p < 0.001) of motor test variance, with the equation: y = -0.329 upper-arm girth + 0.221 triceps skinfold + 0.073 abdominal skinfold + 25.39 (Figure 1e). Finally, for the Shuttle run test, the best-fitting model included three variables: BMI, upper-leg girth and triceps skinfold, which explained about 32% (F = 41.302, p < 0.001) of motor test variance, with the equation: y = -8.65 BMI + 6.28 upper-leg girth – 9.77 triceps skinfold + 310.25 (Figure 1f).

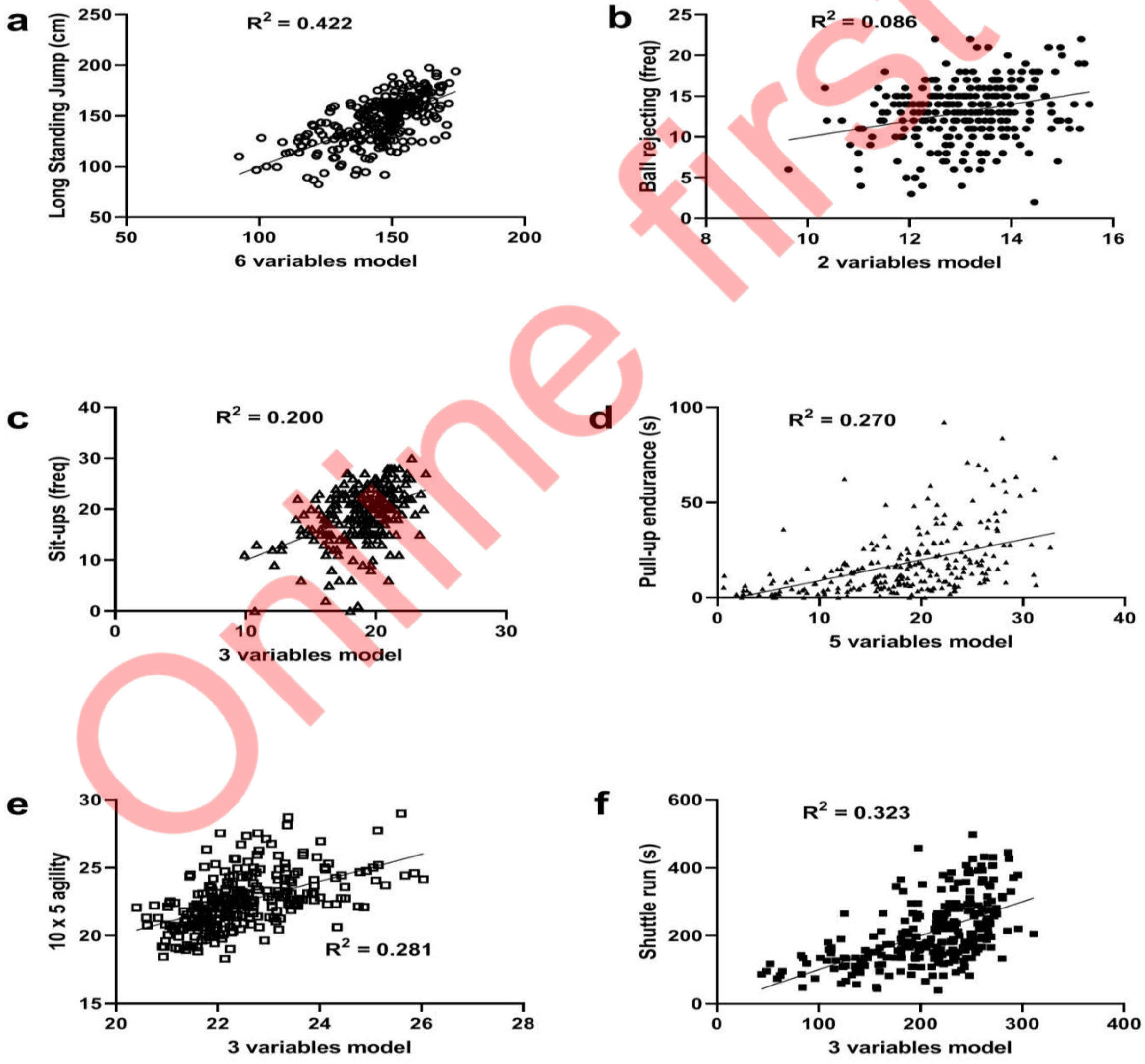

Figure 1. Predicting Long Standing Jump (panel a), Ball rejecting (panel b), Sit-ups (panel c), Pull-up endurance (panel d), 10 x 5 agility (panel e) and Shuttle run (panel f) test based on anthropometric measures

DISCUSSION

The study was conducted to comprehensively investigate associations between anthropometric features and PRF in 10-year-old children. Main results indicate that: i) lower-body explosive strength and aerobic endurance seem to be largely dependent on anthropometric characteristics, particularly skinfold thickness, BMI, and girth measures, ii) components of PRF such as agility, repetitive strength, and strength-endurance have a moderate association with anthropometric features, iii) anthropometric characteristics have negligible influence on performance in motor tests that relies to the flexibility, frequency of movement and motor coordination.

The present results revealed that, at the age of 10 years, girls have greater body mass and height than boys. This is somewhat expected due to different maturation patterns between sexes (i.e. girls have their peak growth spurt approximately 2 years earlier than boys), and our findings are in good agreement with previous literature (Vandendriessche et al., 2012). On the other hand, although some anthropometric dimensions were greater, boys demonstrated better results in the majority of motor tests (except sit and reach, and hand taping tests). Based on this, it seems that morphology offers little explanation for sex differences in motor performance, at least in 10-years old children. A possible reason for the abovementioned differences in PRF between sexes may be due to some environmental factors. Particularly, boys engage in more competitive (sport) games than girls and generally participate in physical activity of longer duration (Ridgers, Stratton, & Fairclough, 2006, Mitić, 2006), which might result that them being more motor proficient than girls.

With respect to the relationship between anthropometry and components of PRF, current results indicate that the influence of body physique tends to vary according to the specific motor test. Particularly, anthropometric features seem to have a negligible effect on performance in motor tests that relies on flexibility and movement frequency. These findings are not surprising considering that flexibility predominantly depends on tendon stiffness (Witvrouw, Mahieu, Roosen, & McNair, 2007), while frequency of movement on neural involvement (Volman, Laroy, & Jongmans, 2006). On the other hand, skinfold thickness and wrist diameter might have some role in motor coordination performance, but this causality is rather trivial. This is consistent with previous literature (Vandendriessche et al., 2011; Luz et al., 2018) in which motor coordination showed a small, but significant correlation with measures of adiposity (i.e. BMI, skinfold thickness, body fat mass), while the link between wrist diameter and motor coordination might be explained through biological maturity (since wrist circumference is a significant indicator of biological maturity) (Beunen, Rogol, & Malina, 2006).

From eight evaluated components of PRF in the current study, explosive strength and aerobic endurance showed to be mostly affected by anthropometric features. Also, anthropometric factors showed to have a moderate influence on repetitive strength, strength endurance, and agility. Specifically, skinfold thickness and BMI showed to be the strongest predictors of performances in almost all motor tests, except in sit-and-reach and hand taping. Concerning skinfold thickness (and BMI), our finding further supports the idea that excessive body fat leads to inferior performances on physical tests which require propulsion or lifting of the body mass (D’Hondt et al., 2009; Esco et al., 2008). Moreover, our results indicate that body fatness probably represents the most important morphological factor for sports performance. Besides skinfold thickness, arm and leg girth showed to be important predictors of agility, aerobic endurance, and all strength components. Greater girth measures indicate greater muscle mass (Cavedon, Milanese, & Zancanaro, 2020) which should be advantageous for strength and running performance (Suchomel, Nimphius, & Stone, 2016). From that perspective, our results are in agreement with previous studies (Esco et al., 2018; Vaara et al., 2012) which established a casual relationship between muscle mass and performance on motor tests to evaluate strength, aerobic endurance, and agility.

For the Long jump test performance, besides skinfold and girth measures, a multivariate model included leg length and wrist diameter and explained about 44% of the test variance. Leg length has been previously shown to be a variable of great interest for lower-body explosive strength (Benefice & Malina, 1996), considering that both the take-off and landing distances of the Standing long jump are strongly affected by leg length (Wakai & Linthorne, 2005). On the other hand, for Sit-ups and Pull-up endurance, the best-fit model explained about 22-27% of the variance. These results indicate that, among various components of strength (i.e. repetitive and explosive strength, strength-endurance) seems to be most affected by morphological status. Interestingly, for Pull-up endurance, arm length showed an inverse correlation. It has been hypothesized that participants who have longer segment lengths, have longer resistance moment arms (Vigotsky et al., 2019), thus longer upper limbs may be a disadvantage for upper-body strength-endurance performance.

Strengths and limitations of the study

The main strength of this study is that we applied a comprehensive approach, including various anthropometric and motor variables, to determine the relationship between morphological features and PRF in young school children. In addition, we believe that our sample size was quite large and representative enough of physical fitness among 10-years old children. Nevertheless, this study is not without limitations. The first limitation refers to the shuttle run test, which, although a valid tool for accessing aerobic performance, is not a direct method for determining aerobic capacity (Armstrong et al., 2011). Second, we used only one test to evaluate motor coordination; coordination is a multidimensional construct and there are different types of coordination (i.e. coordination in rhythm, speed performance in complex motor tasks, etc.) (Vandendriessche et al., 2012). Lastly, note that biological age was not calculated in the present sample, which is the third limitation of the current study.

CONCLUSION

In conclusion, 10 years- old girls have greater body mass, height, and better scores on flexibility tests compared to their male peers. On the other hand, boys demonstrated better results on motor tests to evaluate coordination, strength, agility, and aerobic endurance. Anthropometric factors are important for strength, agility, and aerobic endurance, and inversely, are not related to flexibility, movement frequency, and coordination. Particularly, lower skinfold thickness and greater girth measures seem to be advantageous for performance in motor tests to evaluate explosive strength and aerobic endurance.

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