Research article

Multivariate Relationships among Morphology, Fitness and Motor Coordination in Prepubertal Girls

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Abstract

Motor coordination and physical fitness are multidimensional concepts which cannot be reduced to a single variable. This study evaluated multivariate relationships among morphology, physical fitness and motor coordination in 74 pre-pubertal girls 8.0-8.9 years of age. Data included body dimensions, eight fitness items and four motor coordination tasks (KTK battery). Maturity status was estimated as percentage of predicted mature stature attained at the time of observation. Canonical correlation analysis was used to examine the relationships between multivariate domains. Significant pairs of linear functions between indicators of morphology and fitness ($r_c = 0.778$, Wilks' Lambda = 0.175), and between fitness and motor coordination ($r_c = 0.765$, Wilks' Lambda = 0.289) were identified. Girls who were lighter and had a lower waist-to-stature ratio and % fat mass attained better scores in the endurance run, sit-ups and standing long jump tests, but poorer performances in hand grip strength and 2-kg ball throw. Better fitness test scores were also associated with better motor coordination scores. Relationships between body size and estimated fatness with motor fitness suggested an inverse relationship that was particularly evident in performance items that required the displacement of the body through space, while motor coordination was more closely related with fitness than with somatic variables.

Key words Body size, predicted adult stature, canonical correlation, movement proficiency, KTK test.

Introduction

Motor competence has been defined as the ability to execute motor activities including fundamental movement patterns and fine motor skills that are necessary to manage everyday tasks (Barnett et al., 2016). These attributes are implicit in the daily activities of children and are often assessed using qualitative scales rating proficiency from immature to mature with variable intermediate stages (Gallahue and Ozmun, 2006). Movement patterns and motor skills are central to the Physical Education curriculum. In contrast, physical fitness is often expressed quantitatively (s, cm, kg) and tests are often labeled as health- and performance-related. Health-related fitness characteristically includes cardio-respiratory endurance, muscular strength, flexibility and estimates of body composition (Lobelo et al., 2009) or the body mass index (BMI) which has limitations as an indicator of body composition (Huang and Malina, 2007). Waist circumference has also emerged as an alternative indicator of health-related morphology (Silva et al., 2016) and is often expressed relative to stature. Discussions of the growth and physical fitness of children and youth are often set in the context of physical activity and health, although clear definitions of fitness and an important correlate, motor coordination, are not systematically addressed.

Performances on physical fitness tests are often considered relative to body morphology. The latter reflects size per se, proportions and composition, all of which change during the course of growth, and are associated with individual differences in biological maturation. Skeletal age is often considered the best indicator of biological maturation (Malina et al., 2004) but requires exposure to low dose radiation. As a result, anthropometric estimates of biological maturation have been proposed: percentage of predicted adult (mature) stature at the time of observation which is an indicator of maturity status, while predicted maturity offset or time before peak height velocity is an estimate of maturity timing, although it is often used to classify youth into maturity status groups (Malina, 2014). Both indicators have been used in studies of fitness and motor performance (Malina et al., 2016).

Relationships between indicators of growth and maturation, on one hand, and physical fitness and motor skill, on the other hand, vary with analytical approach and highlight several interactions. Using hierarchical multiple regression, for example, skeletal age alone or interacting with body size had a negligible influence on fundamental motor skills and motor coordination in Portuguese youth 7–10 years and 11-14 years of age (Freitas et al., 2015; 2016). Results of a canonical correlation analysis highlighted interrelationships among morphology, fitness, estimated body composition and motor coordination, and

between fitness and motor coordination in boys 7-11 years (Vandendriessche et al., 2011). Unfortunately, the latter study did not include an indicator of maturity status.

The present study examines multivariate relationships among morphology, estimated biological maturity status, physical fitness and motor coordination in pre-pubertal girls. Linear combinations of variables in the four domains (biological maturation, morphology, fitness and motor coordination) were hypothesized.

Methods

Procedures
The Ethics Committee of the Federal University of Alagoas, Brazil, approved the project (CAAE 09200413.5.0000.5013). The study was also conducted in accordance with the Declaration of Helsinki by the World Medical Association for research with humans (General Assembly of the World Medical Association, 2014), and met the ethical standards for sports medicine (Harriss and Atkinson, 2015). Primary schools from Arapiraca in the state of Alagoas, Northeastern Brazil (230,000 residents) were contacted for cooperation in the project. Parents or legal guardians provided a signed informed consent form (response rate 90%). Participants were informed about the objectives of the study, that participation was voluntary and that they could withdraw at any time. Data collection included three sessions. The first collected personal information and anthropometric data, the second included the tests of physical fitness, and the third session was devoted to the assessment of motor coordination. If necessary, missing data were collected during an additional visit. The data were collected by a team of three trained researchers.

Participants
The focus of study was a cross-sectional sample of 74 girls 8.0 through 8.9 years of age who met four inclusion criteria: (i) neither injured nor affected by a limitation to the performance of the fitness tests, e.g., asthma; (ii) enrolled in the physical education classes involved in the study; (iii) were premenarcheal, and (iv) provided information on the statures of both parents (via questionnaire). The narrow age range was selected to reduce overlapping age-related variation on morphology, fitness performance and motor coordination.

Morphology
Stature (St) and sitting height (SH) were measured to the nearest 0.1 cm with a portable stadiometer (Harpenden stadiometer, model 98.603, Holtain Ltd, Crosswell, UK). Body mass (BM) was measured to the nearest 0.1 kg with a digital scale (Tanita Inner Scan BC 532). Waist circumference (WC) was measured to the nearest 0.1 cm at the approximate midpoint between the lower margin of the last palpable rib and the top of the iliac crest (World Health Organization, 2008) using a non-elastic tape (Lohman et al., 1988). The triceps and medial calf skinfolds were measured to the nearest 1.0 mm using a Lange skinfold caliper (Beta Technology, Ann Arbor, MI, USA). Four variables based on anthropometric dimensions were derived: the body mass index (BMI), the waist circumference to stature ratio (WSR) and the sitting height to stature ratio (SSR)

were calculated. Percentage fat (% fat) was predicted from the triceps and medial calf skinfolds using the appropriate equation of Slaughter et al. (1988).

Physical fitness
Eight fitness tests were administered following the EUROFIT protocols (Committee for the Development of Sports, 1988): static strength (hand grip strength, HGP); functional strength of the trunk (60-s sit-ups, SUP), the upper limbs (2-kg medicine ball throw, 2BT) and the lower limbs (standing long jump, SLJ); flexibility (sit-and-reach, SAR); speed (25-m dash, SPR); agility (10x5-m shuttle run, SHR); and cardio-respiratory endurance (20-m endurance shuttle run, ESR). The battery was selected on the basis of previous experience with primary school children (Vandendriessche et al., 2011). The tests were administered in the following sequence: 2BT, HGP, SLJ, SUP, SAR, SPR, SHR and ESR.

Motor coordination
Gross motor coordination was assessed with the KTK battery (Kiphard and Schilling, 1974; 2007) which included four tasks: walking backward on balance beams (WB), jumping sideways across a wooden slat (JS), moving sideways on boxes (MS), and hopping on one leg for height (HH). The battery has established reliability and validity in children 5–14 years (Kiphard and Schilling, 1974). The four tests were administered in a circuit rotation using four stations. Each station was sufficiently separated so that the participants had no visual contact with other tests. Although the raw scores for each test are commonly transformed using sex-and age-specific tables derived from the original German sample to improve comparability independent of age and sex, or converted to an overall motor quotient (Kiphard and Schilling, 1974), the raw score for each test was retained for analysis in the current study.

Quality control
Replicate measurements of morphological variables and replicate tests of each fitness and coordination item were made/administered by the same observer on 19 participants after a one-week interval. Intra-observer technical errors of measurement (TEM = $\sqrt{[\sum d^2/2n]}$; "d" refers to intra-individual differences) and reliability coefficients (R = 1-$[TEM^2/\sigma^2]$; "σ" corresponds to combined variance) for anthropometric variables were, respectively, as follows (Malina, 1995; Mueller and Martorell, 1988): stature (TEM=0.6 cm; R=0.98), sitting height (TEM = 0.5 cm; R=0.96), body mass (TEM = 0.6 kg; R = 0.99), waist circumference (TEM = 1.6 cm; R = 0.93) and skinfolds (TEM = 1.0-1.4 mm; R=0.94-0.98). Intra-class correlation coefficients (ICC) between the original and replicate tests were used for the fitness and coordination items (Lu and Shara, 2007); coefficients were as follows for fitness variables: ICC = 0.87 (HGP); ICC = 0.84 (SUP); ICC = 0.79 (2BT); ICC = 0.78 (SLJ); ICC = 0.92 (SAR); ICC = 0.78 (SPR); ICC = 0.76 (SHR); ICC = 0.67 (ESR), and for the motor coordination tests: ICC = 0.81 (WB), ICC = 0.80 (JS), ICC = 0.84 (MS); ICC = 0.92 (HH). Results of the replicate analyses indicated reasonable quality, consistency and reliability in the measurement and testing processes under the

conditions of the present study.

Biological maturity status

Adult or mature stature was predicted with sex-specific equations developed on American children resident in the state of Ohio; predictors included chronological age, stature and body mass of the child and mid-parent stature - the average stature of the child's biological mother and father (Khamis and Roche, 1994). Current stature of the child was then expressed as a percentage of predicted mature stature (%PMS) and was used as an indicator of maturity status at the time of observation. Two girls of the same chronological age may have the same stature, but one is closer to mature stature than the other; the former is advanced in maturity status compared to the other (Malina et al., 2004).

Statistical analysis

Descriptive statistics were calculated for all variables. Normality was checked using the Kolmogorov-Smirnov test. If necessary, variables were log transformed to normalize distributions and meet the assumptions of subsequent analyses. Bivariate correlations were calculated to examine associations among chronological age, %PMS, and each item of the anthropometric, fitness and coordination batteries. Correlation coefficients was interpreted using the following thresholds (Hopkins et al., 2009): trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$), and nearly perfect ($r > 0.9$).

Canonical correlation analysis was used to evaluate relationships among morphology (5 items), physical fitness (8 tests) and motor coordination (4 tasks). Each set of variables was collapsed into a canonical variate, the linear combination of variables that maximized the relationship between domains: $Y = a_1Y_1 + a_2Y_2 + \ldots + a_nY_n$; $Z = a_1Z_1 + a_2Z_2 + \ldots + a_nZ_n$). The canonical coefficient ($r_c = r_{y,z}$) provided an indication of the magnitude of association between the two sets of variables, while its squared value (r_c^2) provided an estimate of the shared variance between the two variates. Wilks's Lambda was also used; when significant, only the first pair of canonical variates was interpreted. The sign of correlations was inverted for the two time-based tests (SPR and SHR) as lower scores indicated better performances. Details of the analytical protocol are explained in more detail elsewhere (Vandendriessche et al., 2011). IBM SPSS 22.0 (SPSS, Inc., Chicago, IL) was used for all analyses; statistical significance was set at 5%.

Results

Descriptive statistics and Pearson correlations between variables - chronological age, %PMS, and anthropometric, fitness and coordination items - are summarized in Table 1. Correlations between variables ranged from trivial to high. The magnitude of correlations between chronological age and indicators of morphology ranged from 0.01 to 0.10; corresponding correlations between age and fitness items were <0.12. Correlations were low for two KTK items, but were slightly higher for hopping height (0.12)

and jumping sideways (0.20). On the other hand, correlations between estimated maturity status expressed as %PMS and morphological variables ranged from +0.27 to +0.92. Correlations between %PMS and fitness items ranged from -0.05 to +0.48, and between %PMS and coordination items ranged from -0.16 to -0.28.

Results of the canonical correlation analysis are summarized in Table 2. Two significant linear functions between morphology and fitness (Wilks' Lambda = 0.175; $p < 0.01$; $r_c = 0.778$, $r_c^2 = 0.606$; eigenvalue = 1.538) were apparent. The linear functions explained, respectively, 49.7% and 17.4% of variance in the morphology and fitness domains. The loading of each variable for the respective linear functions are illustrated in Figure 1. Using a critical value >0.40, the main morphological contributors to fitness were the waist circumference to stature ratio (-0.98), the sitting height to stature ratio (-0.77), % fat mass (-0.72) and stature (-0.56), while three fitness tests loaded substantially on the canonical variate: 2-kg ball throw (-0.71), grip strength (-0.67) and the 20-m shuttle run (+0.42).

A significant canonical correlation between morphology and the motor coordination tests was not evident (Table 2, Wilks' Lambda = 0.719, p = 0.313), while a significant pair of linear functions was apparent between fitness and motor coordination (Wilks' Lambda = 0.289; p < 0.01; $r_c = 0.765$; $r_c^2 = 0.585$; eigenvalue = 1.409). Each linear function explained, respectively, 29.5% and 49.5% of the variance in the fitness and motor coordination domains. Fitness variables with a magnitude loading >0.40 on the respective canonical variate included the endurance shuttle run (-0.76), 10x5-m shuttle run (-0.66), 60-s sit-ups (-0.62), the standing long jump (-0.54), sit-and-reach (-0.51) and 25-m dash (-0.45); corresponding variables in the coordination domain included hopping for height (-0.97), jumping sideways (-0.78) and walking backward (-0.45) (Figure 2).

Discussion

The multivariate relationships among morphological, fitness and motor coordination variables were considered in a single chronological age group of pre-pubertal girls (8.0-8.9 years). Canonical correlation analysis did not identify any significant multivariate association between the four motor coordination items and the morphological variables which suggested that motor coordination as measured with the KTK test was independent of inter-individual variation in morphology. The coordination items were also independent of estimated maturity status (%PMS), although girls advanced in maturity status attained lower scores in one coordination item, walking backward (r = -0.28; 95%CI: -0.48 to -0.06). On the other hand, motor coordination had a direct multivariate relationship with physical fitness (Figure 2), which was explained to a large extent by items requiring movement of the body through space – the endurance run, agility shuttle run, standing long jump and sprint. It should also be noted that two other tests, which did not require movement of the body through space, were included among the fitness items, sit-ups and sit-and-reach.

Table 1. Descriptive statistics and Pearson correlations between age and percentage of predicted mature stature and morphological, fitness and motor coordination variables (n = 74).

Variable (abbreviation)	Mean	(95%CI)	SD	Correlations: Xi,Yi; Xi,Zi; Xi,Wi,	
				X1: Chronological age coefficient (95% CI)	X3: %PMS coefficient (95% CI)
X1: Chronological age, years	8.45	(8.39 to 8.52)	.29		
X2: Predicted mature stature, cm	162.3	(160.9 to 163.7)	6.0		
X3: Percentage of PMS, %	80.5	(79.9 to 81.1)	2.5		
Y1: Stature, cm	130.7	(129.3 to 132.0)	5.8	0.19 (-0.04 to 0.40)	0.60 (0.43 to 0.73)
Y2: Body mass, kg	30.4	(28.9 to 32.0)	6.6	0.10 (-0.13 to 0.32)	0.92 (0.88 to 0.95)
Y3: Body mass index, kg.m^{-2}	17.7	(17.0 to 18.5)	3.3	-0.01 (-0.24 to 0.22)	0.81 (0.71 to 0.88)
Y4: Waist circumference, cm	59.5	(57.9 to 61.2)	7.3	0.05 (-0.18 to 0.26)	0.84 (0.76 to 0.90)
Y5: WC-to-stature ratio, %	45.6	(44.4 to 46.8)	5.2	-0.03 (-0.26 to 0.20)	0.68 (0.54 to 0.79)
Y6: Sitting height, cm	68.7	(68.0 to 69.4)	3.2	0.14 (-0.09 to 0.36)	0.71 (0.58 to 0.81)
Y7: SH-to-stature ratio, %	52.6	(52.2 to 52.9)	1.4	-0.08 (-0.30 to 0.15)	0.27 (0.04 to 0.47)
Y8: Fat percentage, %	28.1	(26.7 to 29.5)	6.1	-0.07 (-0.29 to 0.16)	0.67 (0.52 to 0.78)
Y9: Fat mass, kg	8.9	(8.0 to 9.8)	3.9	0.01 (-0.22 to 0.24)	0.84 (0.76 to 0.90)
Y10: Fat free mass, kg	21.6	(20.8 to 22.3)	3.2	0.14 (-0.09 to 0.36)	0.86 (0.79 to 0.91)
Z1: 2-kg medicine ball throw, cm	175	(168 to 182)	29	0.06 (-0.17 to 0.29)	0.48 (0.28 to 0.64)
Z2: Hand grip strength, Kgf	12.1	(11.3 to 12.8)	3.2	0.09 (-0.14 to 0.31)	0.47 (0.27 to 0.63)
Z3: 60-s sit-ups, #	14.9	(12.8 to 17.0)	8.9	-0.02 (-0.25 to 0.21)	-0.22 (-0.43 to 0.01)
Z4: Standing long jump, cm	82	(76 to 87)	24	0.12 (-0.11 to 0.34)	-0.11 (-0.33 to 0.12)
Z5: Sit-and-reach, cm	26.1	(24.8 to 27.5)	5.8	0.10 (-0.13 to 0.32)	-0.15 (-0.37 to 0.08)
Z6: 25-m dash, s	6.40	(6.22 to 6.59)	0.80	0.08 (-0.15 to 0.30)	0.16 (-0.07 to 0.38)
Z7: 10x5-m shuttle run, s	27.54	(26.96 to 28.12)	2.51	0.08 (-0.15 to 0.30)	-0.05 (-0.28 to 0.18)
Z8: Endurance 20-m, m	268	(239 to 298)	126	0.08 (-0.15 to 0.30)	-0.32 (-0.51 to -0.10)
W1: Walking backward, #	38.6	(35.7 to 41.5)	12.5	-0.01 (-0.24 to 0.22)	-0.28 (-0.48 to -0.06)
W2: Jumping sideways, #	29.9	(27.8 to 32.1)	9.4	0.20 (-0.03 to 0.41)	-0.16 (-0.38 to 0.07)
W3: Moving sideways, #	31.4	(29.6 to 33.4)	8.2	-0.04 (-0.27 to 0.19)	-0.22 (-0.43 to 0.01)
W4: Hopping for height, #	29.8	(26.9 to 32.8)	12.6	0.12 (-0.11 to 0.34)	-0.18 (-0.39 to 0.05)

95%CI (95% confidence interval); # (Counts); the sign was inverted for the SPR and SHR since lower scores correspond to better performances. SD (standard deviation).

Table 2. Results of the canonical correlation analyses among morphology and fitness, morphology and motor coordination and between fitness and motor coordination in 8 years old girls.

	Multivariate domains		
	Yi: morphology x Zi: Fitness	Yi: morphology x Wi: coordination	Zi: Fitness x Wi: coordination
r_c	0.778	0.387	0.765
r_c^2	0.606	0.150	0.585
Eigenvalue	1.538	0.176	1.409
Wilks' Lambda (p)	0.175 (<0.01)	0.719 (0.318)	0.289 (<0.01)
% variance (Yi)	49.7%		
% variance (Zi)	17.4%		29.5%
% variance (Wi)			45.4%
Y$_1$: Stature (St)	-0.56		
Y$_2$: Body mass (BM)	-0.31		
Y$_7$: SH-to-stature ratio (SSR)	-0.77		
Y$_5$: WC-to-stature ratio (WSR)	-0.98		
Y$_5$: Fat percentage (%fat)	-0.72		
Z$_1$: 2-kg ball throw (2BT)	-0.71		-0.32
Z$_2$: Hand grip strength (HGP)	-0.67		-0.31
Z$_3$: 60-s sit-ups (SUP)	+0.33		-0.62
Z$_4$: Standing long jump (SLJ)	+0.29		-0.54
Z$_5$: 25-m dash (SPR)	-0.11		-0.45
Z$_6$: 10x5-m shuttle run (SHR)	-0.14		-0.66
Z$_7$: Endurance 20-m (ESR)	+0.42		-0.76
Z$_8$: Sit-and-reach (SAR)	+0.19		-0.51
W$_1$: Walking backward (WB)			-0.45
W$_2$: Jumping sideways (JS)			-0.78
W$_3$: Moving sideways (MS)			-0.24
W$_4$: Hopping for height (HH)			-0.97

SH (sitting height); WC (waist circumference). The sign was inverted for the SPR and SHR since lower scores correspond to better performances.
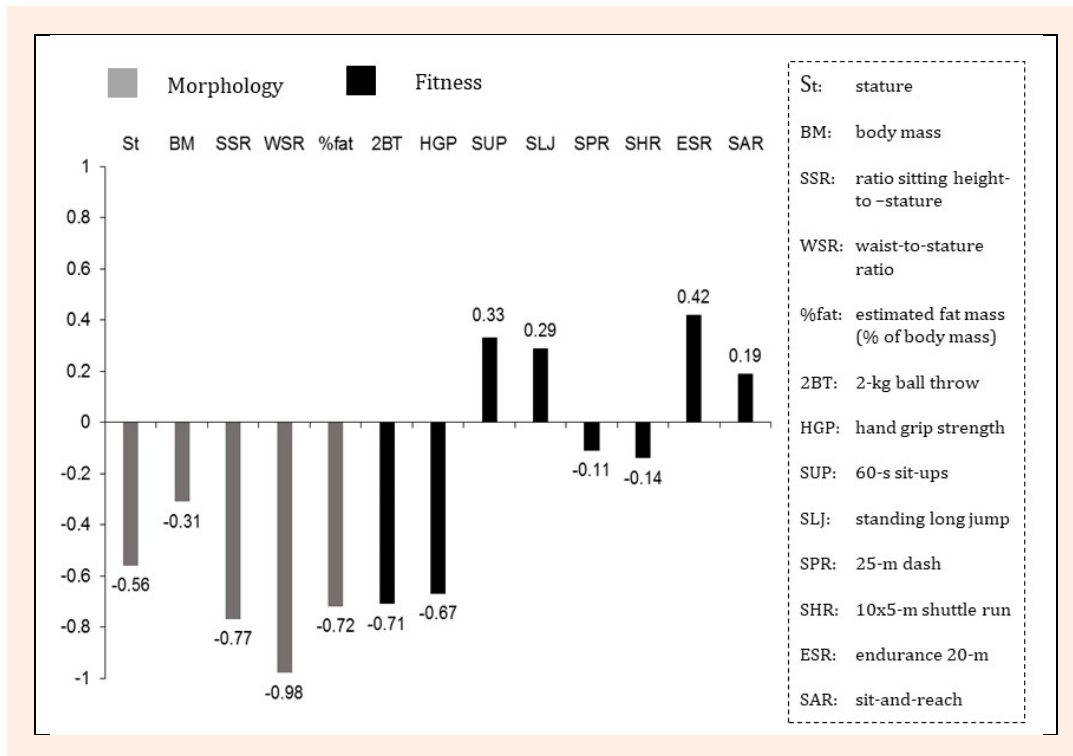
Figure 1. Correlations of morphological and physical fitness variables with their respective first canonical variates. The signs were inverted for the SPR and SHR since lower scores indicate better performances.
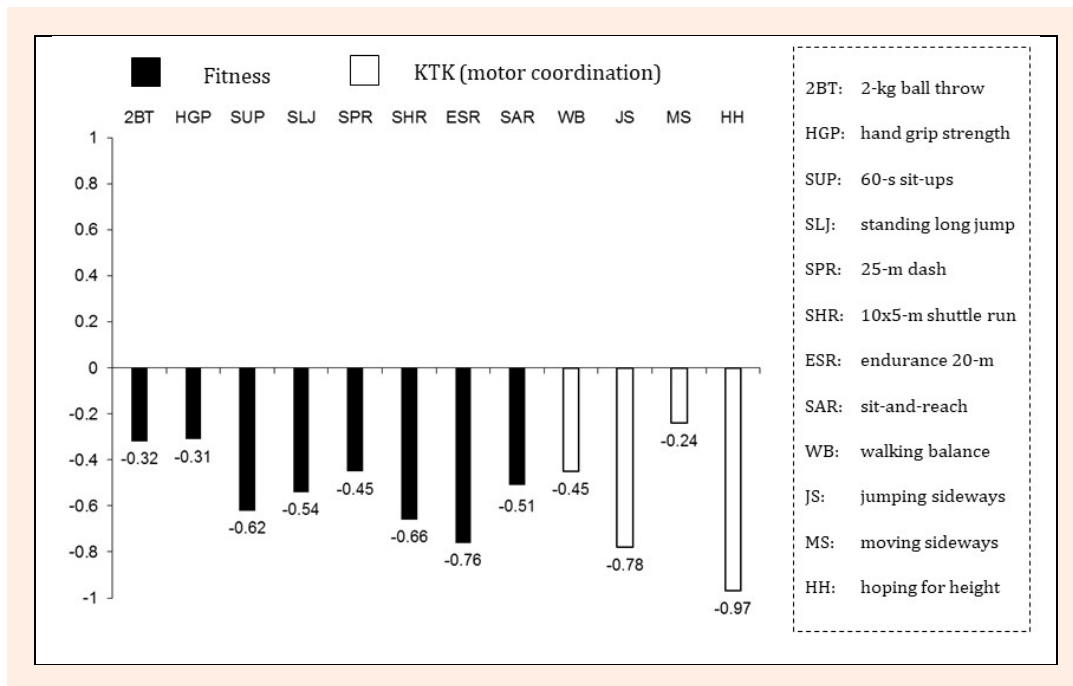
Figure 2. Correlations of physical fitness and motor coordination items with their respective first canonical variates. The sign was inverted for the SPR and SHR since lower scores indicate better performances.

The bivariate correlations indicated trivial univariate relationships between individual fitness items requiring body displacement and the non-invasive estimate of maturity status used in the present analysis. Nevertheless, the preceding observations were generally consistent with regression analyses including age, body mass, stature and skeletal age as the indicator of maturity status. In a study of girls spanning 6-16 years, skeletal age separately or in combination with chronological age and stature or body mass were not significant predictors of the standing long and vertical jumps and a shuttle run; on the other hand, physical working capacity and upper arm strength were positively correlated with skeletal age (Beunen et al., 1997). Given the relationship between skeletal and chronological ages (Malina et al., 2004), several studies have used the standardized residual of the regression of skeletal

age on chronological age as the indicator of maturity status. Results of a regression analysis including age, body mass, stature and the standardized residual of skeletal age showed modest coefficients of determination for the dash, standing long jump and ball throw for distance throw among girls 7-12 years (Katzmarzyk et al., 1997), while a similar analysis among girls 7-10 years noted that the standardized residual of skeletal age by itself accounted for a maximum of 9% of variance in fundamental motor skills and motor coordination (KTK) over that attributed to body size per se and the interactions between body size and the residuals of skeletal age on chronological age (Freitas et al., 2015). By inference, other determinants, e.g., neuromuscular maturation, opportunities to play without supervision, participation in organized sports, and others may influence motor coordination at these ages.

In contrast to the preceding studies, predicted age at peak height velocity (PHV) was used as the maturity indicator in a comparison of motor coordination (KTK) in normal weight and overweight/obese boys and girls 6–10 years of age (D'Hondt et al., 2013). The results indicated a negative influence of overweight/obesity on motor coordination and suggested predicted age at PHV as a significant covariate of the four coordination items. Age at PHV is an indicator of the timing of a pubertal event and as such its use among children 6-10 years of age is problematic. Moreover, the sex-specific prediction equations have major limitations; predicted ages at PHV vary with chronological age at prediction, have a reduced range of variation in contrast to variation in observed ages at PHV in longitudinal studies, are overestimated (later than observed) in early maturing children, and are underestimated (earlier than observed) in late maturing children (Malina and Kozieł, 2014; Malina et al., 2016; Kozieł and Malina, 2018).

The KTK test of motor coordination has been commonly used in studies addressing associations among coordination, physical activity and health in youth (Cools et al., 2009). Using the normative data for the German sample upon which the test was developed (Kiphard and Schilling, 1974), raw scores on each of the four KTK tests are commonly converted into standardized scores adjusting for age (all items) and sex (hopping for height and jumping sideways over a slat), which are then converted into an overall motor quotient for analysis (D'Hondt et al., 2011; Krombholz, 2006; Lopes et al., 2012; 2013). Some authors have also done separate analyses for each KTK item (Luz et al., 2016a; 2016b; Vandendriessche et al., 2012; Vandorpe et al., 2011), while others (Lopes et al., 2012; 2013; 2015; Vandorpe et al., 2011) have used the motor quotient as a global indicator of motor coordination. Scores of the four KTK tests were not transformed in the present analysis. Rather, canonical correlation analysis permitted the incorporation of multiple variables in their original units.

The current study has several limitations that should be recognized. It is limited to a cross-sectional sample of girls and used a %PMS as the indicator of maturity status. On the other hand, use of a single chronological age group reduced potential age-associated variation, which facilitated the interpretation of the multivariate nature of relationships among morphology, physical fitness and motor

coordination. Future research using multivariate analysis using canonical correlation should include an indicator of physical activity to improve our understanding of the inter-relationships among growth, maturation, fitness, motor coordination and habitual physical activity.

Conclusion

Few studies have examined the multivariate association among morphology, fitness and motor coordination in young girls. Results of the current study demonstrated a moderate multivariate relationship between morphology and fitness and also between fitness and motor coordination. In contrast, the overlapping variance between morphology and motor coordination was negligible. The results suggested that other factors not considered in the present analysis influenced the fitness and motor coordination of 8 year old girls. These likely include the built environment, socioeconomic status, parental physical activity and involvement in the activities of their children, sibling and peer interactions, rearing style, opportunities for free play, habitual physical activity, participation in organized sports, among others.

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Key points

- Morphology and motor coordination were not substantially related in this sample of 8-year-old girls suggesting that motor coordination was independent of variation in morphology.

- Sit-ups (abdominal strength and endurance), the 10x5-m shuttle run (agility) and the 20-m aerobic endurance tests were the main contributors to the significant canonical correlation between fitness and motor coordination. By inference, development of these components of fitness is important during the primary school years.

- Relationships between estimated maturity status based on percentage of predicted mature height and fitness and coordination were negligible, with the exception of a moderate and inverse association with aerobic endurance. Nevertheless, within the single chronological age group, girls who were advanced in maturity status tended to taller and heavier and performed better in tests which did not require displacement of the body through space.

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