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original article

Body composition in portuguese adolescents: are physical activity and maturity status sex-specific determinant factors?

Composição corporal em adolescentes portugueses: a atividade física e a maturidade são fatores determinantes específicos do sexo?

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Abstract – The influence of biological maturation and physical activity (PA) on the differences of body composition in adolescents have been little studied. The purpose of this study was to examine if PA and maturity status were sex-specific determinant factors in the adolescents' body composition. Ninety-four adolescents (50 boys and 44 girls) were evaluated. All anthropometric measures were obtained according to ISAK procedures, bone age was estimated by the TW3 method, and PA was assessed with *Actigraph*® GT1M, over seven consecutive days. Maturity status explained 33% of the body mass index (BMI) and waist circumference (WC) and 31% of the sagittal abdominal diameter (SAD) in boys. In girls, maturity status explained 27% of the waist-to-hip ratio (WHR), moderate PA explained 17% of the BMI and 12% of the WC, and moderate to vigorous PA explained 11% of the SAD. These results seem to indicate that the determinant factors of the adolescents' body composition are sex-specific. Maturity status was the main predictive factor in boys and interacted with PA in girls. Our findings support the evidence that researchers need to consider biological maturity when explaining body composition changes in adolescents.

Key words: Adolescent; Body composition; Maturity; Physical activity.

Resumo – *A influência da maturação biológica e atividade física (AF) nas diferenças de composição corporal em adolescentes tem sido pouco estudada. O objetivo deste estudo foi examinar se, na composição corporal dos adolescentes, a AF e a maturidade eram fatores determinantes específicos do sexo. Foram avaliados noventa e quatro adolescentes (50 meninos e 44 meninas). Todas as medidas antropométricas foram obtidas de acordo com os procedimentos do ISAK, a idade óssea foi estimada pelo método TW3 e a AF foi avaliada com o Actigraph® GT1M, durante sete dias consecutivos. A maturidade explicou 33% do índice de massa corporal (IMC) e da circunferência da cintura (CC) e 31% do diâmetro abdominal-sagital (DAS), nos rapazes. Nas raparigas, a maturidade explicou 27% do índice cintura-anca (ICA), a AF moderada explicou 17% do IMC e 12% da CC e, a AF moderada--a-vigorosa explicou 11% do DAS. Estes resultados parecem indicar que os fatores determinantes da composição corporal dos adolescentes são específicos do sexo. A maturidade foi o principal fator preditivo nos rapazes e, em conjunto com a AF moderada, nas raparigas. Os nossos resultados suportam a evidência de que os investigadores precisam considerar a maturidade biológica quando explicam as alterações da composição corporal nos adolescentes.*

Palavras-chave: *Adolescente; Atividade física; Composição corporal; Maturidade.*

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INTRODUCTION

Engagement in regular physical activity (PA) offers health benefits for children and adolescents, since it helps to improve cardiovascular health (by reducing blood pressure, raising high-density lipoprotein levels and lowering low-density lipid levels); musculoskeletal health (by building and maintaining healthy bones and muscles) and psychological health (by reducing anxiety and raising self-esteem). Furthermore, PA has a preponderant role to play in effecting changes in body composition in and preventing overweight and obesity[1].

It has been recognized worldwide that in order to enjoy the many different components of health-related benefits, it is necessary to engage in at least sixty minutes of daily physical activity at moderate to vigorous intensities (MVPA)[2]. In mainland Portugal, just 36% of Portuguese children/adolescents aged 10 to 17 years fulfill these guidelines[3].

While adolescents' body composition can be related to PA, there is also an inherent maturation process that should be taken into consideration. Therefore, since each individual takes their own path to maturity[4], degree of maturity should always be considered in studies involving adolescents, in order to avoid drawing misleading conclusions[4-6].

Several authors have found that time spent engaged in PA (including MVPA) decreases as chronological age increases, in both sexes, and that the boys are more physically active than girls during childhood and through adolescence[6-8]. When aligned with maturation, results remain significant and negatively correlated with PA. However, despite the fact that boys continue to be more active than girls, sex differences do not remain significant[6]. Rather, the sex-linked differences in MVPA are attenuated when maturation is controlled for, and girls spend significantly more time in engaged sedentary behaviors than boys, especially at weekdays[8]. Therefore, consistent findings suggesting that adolescent girls are less active than boys can actually be masked by maturity status, since, on average, girls mature approximately two years before boys, with a sex gap of approximately 1.65 years (11.89 ± 0.58 years *vs.* 13.54 ± 0.81 years), and this advanced maturity appears to modify their PA behavior early on[5,6].

During puberty, hormonal fluctuations are accompanied by marked changes in body composition. Increasing production of gonadal steroids affects adolescents' body composition as follows: the anabolic effect of gonadal testosterone increases the percentage of fat-free mass in boys; whereas gonadal estrogen production after menarche increases percentage of fat mass in girls[9]. A recent longitudinal analysis found significant increases in fat mass among girls during the first year after menarche, pointing to the fact that puberty has an influence on fat mass[10].

In a longitudinal analysis about the role PA plays in controlling fat-free mass that controlled for maturity status, some authors have concluded that muscle development is in part driven by PA, but the gains are higher among boys than girls[11]. Furthermore, positive associations (for the lower body only) were found between vigorous PA and muscle strength in adolescent boys but not in girls, controlling for age, maturity status and fat-free mass[12].

Research conducted with children and adolescents has already shown that sex differences exist in PA behaviours and in body composition, highlighting the importance of controlling for biological age. Notwithstanding, this study is unique in examining the relative contribution of PA and maturity status to variability of body composition in adolescents.

Therefore, with regard to the above, the main objective of this study is to determine whether PA and maturity status are sex-specific determinant factors of body composition in adolescents.

METHODS

Study Design

This was a cross-sectional study at two public schools in the outskirts of Lisbon and was approved by the Scientific Council at the Faculty of Human Kinetics and by the schools' directors. The study was conducted in accordance with the provisions of the World Medical Association's Helsinki Declaration on research involving humans[13]. Informed consent forms were distributed to adolescents' guardians at a meeting designed to inform them of the study objectives. After permission to take part had been granted, the data were collected during physical education classes.

Study sample

The sample consisted of 94 adolescents in the 7th, 8th and 9th grades of high school, all free from disabilities. The majority of the study sample were white. Mean age was 13.4±0.9 years, ranging from 12.1 to 15.8 years and there was no statistically significant age difference between sexes (boys: 13.3±1.0 years; girls: 13.5±0.9 years) (Table 1).

Instruments and procedures

PA was assessed using accelerometry and the output data included the following activity intensity levels: Sedentary Activity (SA), Light Physical Activity (LPA), Moderate Physical Activity (MPA), Vigorous Physical Activity (VPA) and Moderate to Vigorous Physical Activity (MVPA).

These outputs were provided by an Actigraph uniaxial accelerometer (model GTM1, Fort Walton Beach, FL, USA). Accelerometers were initialized as described by the manufacturer (ActiLife Lifestyle software, version 3.2) and were distributed and collected face-to-face by the research team. The adolescents were instructed to wear them on the right hip (as close as possible to the body's center of mass) for seven consecutive days[14]. Accelerometers were removed during sleep and aquatic activities (e.g. bathing, swimming). Data were analyzed using Mahuffe v.1.9.0.3 software.

Data was considered valid if a given adolescent had accelerometer counts for a minimum of ten hours' recording for at least three weekdays, plus one day at the weekend, also with ten hours worth of recording[15], giving a total of 600 minutes per day. Data were saved in 15-s epochs[14,15]. Consecutive zero readings with duration of sixty minutes or greater were considered indicative of the device not being worn.

Metabolic Equivalent (METs) were estimated from the count values using an equation proposed by Freedson for predicting energy expenditure which has been previously employed and validated in children and adolescents aged 6 to 18 years old. The equation is as follows:

$$MET = 2.757 + (0.0015 \cdot count \cdot min^{-1}) - (0.08957 \cdot age(yr)) - (0.000038 \cdot counts \cdot min^{-1} \cdot age(yr)).$$

The threshold for MPA was set at 4 METs and the VPA lower limit was set at 7 METS[7].

Bone age was estimated by the TW3 method[16] with an X-ray of the left hand and wrist using portable X-ray equipment (Ascot 110 model) and Kodak Min-R film. Maturity status was evaluated on the basis of the difference between Bone Age (BA) and Decimal Age (DA).

The baseline anthropometric measures used to estimate body composition were as follows: height, body mass, waist circumference (WC), hip circumference, sagittal abdominal diameter (SAD) and skinfold thicknesses (triceps, subscapular, supraspinale, and front thigh). Thereafter, body mass index (BMI), waist-to-hip ratio (WHR) and the sum of all four skinfolds (summed skinfolds) were calculated.

Participants were instructed to wear light clothing and remove footwear and jewelry. Measurements were taken on the right side of the body using the DKSH Kit (formerly Siber-Hegner GPM), a Rosscraft tape, a Slimguide skinfold caliper and a Seca Vogel & Halke Balance, model 761 7019009.

Data were collected by anthropometrists who had been certified in accordance with the International Society for the Advancement of Kinanthropometry's (ISAK) standard procedures[17].

Data Analysis

Data were analyzed using SPSS version 21.0 (SPSS Inc., an IBM Company, Chicago). For all tests, statistical significance was set at $\rho<0.05$.

Descriptive statistics (means and standard deviations) were calculated for maturational, anthropometric, body composition and PA variables and stratified by sex. The Kolmogorov-Smirnov test and Levene's test were employed to test for normal distribution and homogeneity of variance respectively. Mean values for the different parameters were compared between boys and girls using Student's *t* test for continuous variables or the Mann-Whitney test if they did not fulfill prior assumptions. Multifactorial linear regression models (stepwise method) were subsequently constructed for each gender in order to identify determinant factors (maturity status and PA variables) of BC variables. Adjusted r^2 was used to define the model's goodness of fit.

Multifactorial linear regression models were constructed for each dependent variable (i.e. BMI, WHR, SAD, WC and summed skinfolds), broken down by sex. All models contained six independent variables: SPA, LPA, MPA, VPA, MVPA and BA-DA.

RESULTS

Descriptive statistic for chronological age, maturity status, body composition and PA characteristics of the 94 participants are summarized in Table 1. The results show that although boys and girls did not differ significantly in chronological age (13.3±1.0 years vs. 13.5±0.9 years, ρ=0.201), girls were more mature with older bone age (12.7±1.6 years vs. 14.1±1.9 years, ρ=0.001) and, as a consequence, had a greater difference between bone age and decimal age (-0.6±1.4 years vs. 0.6±1.3 years, ρ<0.001).

Table 1. Descriptive analysis stratified by sex (demographic, maturational, body composition and physical activity variables)

	n	Boys Mean±SD	n	Girls Mean±SD
Demographic				
Decimal Age (years)	44	13.3±1.0	35	13.5±0.9
Maturational				
Bone Age (years)*	44	12.7±1.6	35	14.1±1.9
Bone Age - Decimal Age (years)**	44	-0.6±1.4	35	0.6±1.3
Body Composition				
Body Mass (kg)	49	49.0±10.6	40	52.0±10.2
Height (cm)	49	158.9±7.8	40	159.5±9.1
Body Mass Index (kg/m^2)	49	19.2±2.9	40	20.4±2.9
Waist Circumference (cm)	49	67.7±6.5	40	67.4±6.8
Sagittal Abdominal Diameter (cm)	49	17.3±2.0	40	17.6±2.3
Waist to Hip Ratio**	49	0.81±0.03	40	0.75±0.05
Summed Skinfolds (mm)**	49	41.4±17.7	40	57.5±19.9
Physical Activity				
Sedentary Activity*	50	574.6±71.1	44	621.2±68.0
Light Physical Activity*	50	216.6±45.2	44	193.1±33.4
Moderate Physical Activity**	50	45.9±17.2	44	31.9±11.6
Vigorous Physical Activity**	50	7.9±6.5	44	2.8±2.3
Moderate to Vigorous Physical Activity**	50	53.8±22.3	44	34.7±12.5

*p<.01; **p<.001; Bone Age - Decimal Age = Difference between bone age and decimal age

Differences in body composition between the sexes were as follows. Girls had higher mean values for body mass, stature, BMI, SAD and summed skinfolds, although only the last of these differences was statistically significant (57.5±19.9mm *vs.* 41.4±17.7mm, ρ<0.001). Boys only exhibited higher mean value for WC and WHR, with a statistically significant difference in the latter of these (0.81±0.03 *vs.* 0.75±0.05, ρ<0.001).

Boys were significantly more active for all levels of PA considered. On average, the boys spent more time in LPA (216.6±45.2 min.day^{-1} *vs.* 193.1±33.4 min.day^{-1}, ρ=0.005); MPA (45.9±17.2 min.day^{-1} *vs.* 31.9±11.6 min.day^{-1}, ρ<0.001); and VPA (7.9±6.5 min.day^{-1} *vs.* 2.8±2.3 min.day^{-1}, ρ<0.001); MVPA (53.8±22.3 min.day^{-1} *vs.* 34.7±12.5 min.day^{-1}, ρ<0.001). The only exception was SA (574.6±71.1 min.day^{-1} *vs.* 621.2±68.0 min.day^{-1}, ρ=0.002), which was significantly higher in girls than in boys.

The greatest PA sex differences were in SA (girls spent 46.6 min.day^{-1} more in SA), LPA (boys spent 23.5 min.day^{-1} more in LPA) and MVPA (boys spent 19 min.day^{-1} more in MPVA).

Determinant factors for the body composition variables are presented in Table 2 and Table 3 for boys and girls respectively.

Our results showed that the determinant factors of these adolescents' body composition differed by sex. Maturity status was the single determinant factor of boys' body composition and was the greatest factor in girls' body composition. However, PA (specifically MPA and MVPA) proved to be a consistent factor in girls' body composition. Furthermore, it is noteworthy that no determinant factors were identified for summed skinfolds in either sex.

Analysis of the regression models for boys leads to the conclusion that maturity status explained 33% of the variability in BMI (β=0.571; ρ<0.001), 33% of variation in WC (β=0.576; ρ<0.001) and 31% of changes in SAD (β=0.557; ρ<0.001). Furthermore, no determinant factors were identified for WHR in boys.

Table 2. Regression models for boys

		Body Mass Index		
	Constant	β (p)	95% CI	r^2
Bone Age-Decimal Age	20.054	0.571 (<.001)	0.667-1.751	0.33
		Waist Circumference		
	Constant	β (p)	95% CI	r^2
Bone Age-Decimal Age	69.404	0.576 (<.001)	1.526-3.945	0.33
		Sagittal-Abdominal Diameter		
	Constant	β (p)	95% CI	r^2
Bone Age-Decimal Age	17.781	0.557 (<.001)	0.425-1.163	0.31

Bone Age-Decimal Age= Difference between Bone Age and Decimal Age; No predictive factors were identified for the Waist to Hip Ratio or Summed Skinfolds.

Table 3. Regression models for girls

		Body Mass Index		
	Constant	β (p)	95% CI	r^2
Moderate Physical Activity	17.403	0.407 (.015)	0.020-0.178	0.17
		Waist Circumference		
	Constant	β (p)	95% CI	r^2
Moderate Physical Activity	61.501	0.352 (.038)	0.012-0.386	0.12
		Waist to Hip Circumference		
	Constant	β (p)	95% CI	r^2
Bone Age-Decimal Age	0.761	-0.520 (.001)	-0.035-(-0.009)	0.27
		Sagittal-Abdominal Diameter		
	Constant	β (p)	95% CI	r^2
Moderate to Vigorous Physical Activity	15.642	0.336 (.048)	0.000-0.120	0.11

Bone Age-Decimal Age= difference between bone age and decimal age. No predictive factors were identified for the Summed skinfolds.

On the other hand, in girls maturity status explains 27% of variability in WHR (β=-0.520; ρ=0.001), MPA explains 12% of WC variation (β=0.352; ρ=0.038) and 17% of change in BMI (β=0.407; ρ=0.015), while MVPA explains 11% of SAD variability (β=0.336; p=0.048).

DISCUSSION

This cross-sectional study aimed to determine whether PA and maturity status are sex-specific determinant factors of adolescent body composition. In the event, our results indicated that maturity status is the main determinant factor of body composition variability in these adolescents and also that PA is a determinant factor of these girls' body composition.

The changes that take place during adolescence are gradual and vary across individuals[6]. However, it is widely accepted that girls mature earlier than boys, which is consistent with the results observed in the present study (with statistically significant differences in maturity status between sexes). Considering these results, it can be assumed that the fact that boys were less mature may itself be the reason why maturity status was the single factor that determined body composition (explanatory power ranged from 31% to 33%). On the other hand, since the girls were more advanced in terms of maturity, PA (MPA and MVPA) also played a significant role in the variability of their body composition.

Our study found significant inter-sex differences in the time spent engaged in all levels of PA intensity per day, with boys spending longer periods active, which is in agreement with previous findings[3,6,7]. However, the differences in maturity status between the sexes may be one reason why research consistently shows that girls are less active than boys of the same chronological age[6]. Moreover, it is noteworthy that girls spent more time engaged in SA than boys, which is congruent with some authors' findings[8]. However, these differences became non-significant when maturity is controlled for[8]. Furthermore, other authors have identified a multitude of barriers to PA adherence, which were dependent on grade but independent of maturity status[18]. From this finding we can also suppose that the higher SA values in girls may stem from such barriers, which is worrying. According to a systematic review, SA for more than two hours per day is associated with unfavorable body composition in school-age children and young people and reducing SA is associated with a reduction in BMI[19]. It is therefore considered that there a pressing need to reduce SA among adolescent girls.

A systematic review concluded that the school-age children should participate in a minimum of sixty minutes of MVPA per day in order to reduce the incidence of chronic diseases in adulthood[1]. The adolescents in our sample are plainly falling short of these guidelines, especially the girls. In fact, the girls only engage in exercise for 58% of the time recommended by guidelines for their ages, while the boys engage in exercise for 90% of the recommended duration.

Some authors found an average PA sex gap of 11% for MVPA and of 45% for VPA, supporting the idea that the majority of the sex gap was due to girls participating little in VPA[7]. These findings are in accordance with our results, where the average MVPA sex gap is 19 $min.day^{-1}$ and girls spend on average half the time of boys engaged in VPA.

Some authors support the idea that VPA is a significant predictor of adiposity (more so than MPA)[20] and have found it to be significantly associated with weight status[21]. Therefore, we propose that in order to effect the desired changes in body composition, these adolescent girls should follow their daily PA guidelines, specifically by spending more spending more time engaged in VPA.

We can also conclude that the inverse relation between both MPA and MVPA with body composition variables (BMI, WC and SAD) is related to the low levels of PA performed by our adolescents.

On the subject of body composition variables, it can also be perceived that the adolescents studied here were not at risk of overweight (boys: 19.2±2.9 kg/m^2, girls: 20.4±2.9) based on BMI cut-off points (21.91 kg/m^2 for boys; 22.98 kg/m^2 for girls)[22]. Furthermore, girls are at a more advanced stage of maturity and have higher BMI than boys and according to some authors, children with higher BMIs are more prone to advances in skeletal maturity and to becoming overweight adults[23]. These authors also stated that significant differences in height start at approximately the age of 10 years and peak at approximately 12 years. The girls in our study were also taller and heavier than the boys and, with reference to the NHANES III[24] anthropometric standards for height and body mass, we can conclude that the major difference is in height, with boys at the 25th percentile but girls at the 50th percentile.

The SAD has been considered a reliable indicator of visceral adiposity among children and adolescents[25] and significant sex differences have been found in an adult sample[26]. In our study sample the girls had a higher mean SAD value than boys, but the difference was not significant statistically. It is also noteworthy that both studies used the supine position to obtain this measure, while we used the standing position, as recommended by ISAK. This issue therefore needs further investigation in adolescents.

Mean summed skinfolds were significantly higher in girls than in boys and is assumed that this too is a consequence of their more advanced maturity status, since puberty leads to an increase in fat mass in girls[10]. Nevertheless, our sample is not a cause for concern, because summed skinfolds matched the 50th percentile[24]. Moreover, a longitudinal study found that PA levels fluctuated considerably over time and appeared to affect body composition[27]. These fluctuations were larger for boys than girls, which suggest that greater PA fluctuations are unfavorable for boys and beneficial for girls[27]. Other authors concluded that VPA and even MPA can reduce adiposity and increase cardiorespiratory fitness[20]. The absence of skinfold predictors may therefore be explained by the lower levels of MPA and VPA.

Waist to Hip Ratio and WC were both higher in boys than in girls. Some authors conclude that these measures are effective for determining adolescents' trunk adiposity, and have suggested cut-off values for WC (76.9 cm for boys, at age of 13 years; 77 cm for girls, at age of 14 years)[28]. Since our results (67.7±6.5 cm in boys, with an average age of 13.3 years and 67.4±6.8 cm in girls, with an average age of 13.5 years) were lower than the suggested cut-off values, it can be concluded that these adolescents were not at risk. Furthermore, a comparison with data from a large sample of 2160 Spanish adolescents puts our WHR and WC results below the 50th percentile[29].

Waist to Hip Ratio was significantly higher in boys than in girls, but neither PA nor maturity status proved to be a predictive factor in boys. On the other hand, 27% of girls' WHR variation was explained by maturity status, exhibiting an inverse relationship. In other words the WHR decreases as maturation progresses, which might be due to decreases WC and increased hip circumference, either alone or simultaneously, leading to a gynoid fat distribution. This fat distribution is favorable to girls, since greater deposition of central fat (android distribution) is associated with less favorable plasma lipid and lipoprotein concentrations, blood pressure, and left ventricular mass[30].

The strengths of this study comprise the methods employed to determine PA and maturity status, since accelerometry offers multiple advantages over other objective methods,[15] and the hand-wrist X-ray is the best method for assessing biological maturity[5].

Nevertheless, while accelerometry is an objective method of PA assessment, the method might itself have changed the adolescents' regular activity, particularly the girls, since the accelerometers clashed with their ideas about style and fashion, which resulted in gaps in the data. It is highly recommended to use an incentive to promote accelerometer compliance (e.g. reminder calls, rewards).

The design and implementation of school-based PA needs to consider the variation in physical maturity within sexes and grades[6], in order to improve intervention programs in adolescents (e.g. coaches and physical education teachers could provide specific tasks for athletes/students based on physical maturity instead of CA). Hence, since adolescence is a critical phase for abandonment of PA (especially among girls) and even as adolescents and many adolescents are already below the worldwide health recommendations, it is the duty of stakeholders in the educational process (e.g. teachers, family members) to develop intervention programs in order to promote a basis for healthier adults, aiming at fulfillment of these guidelines. Promoting commitment to regular PA and reduction of SA ought to be one of stakeholders' concerns and should be achieved gradually, starting during childhood, which is in agreement with some authors[20].

CONCLUSION

In conclusion, our findings suggest that PA and maturity status are indeed sex-specific determinant factors of adolescent body composition. Maturity status is the sole predictive factor that consistently explains body composition variability in boys, whereas maturity status, MPA and MVPA were predictive factors that explained body composition variability in girls. Therefore, assuming that girls are more mature than boys at the same chronological age, maturational variability is lower among girls. Thus, time spent in PA seems to be a determinant factor for their body composition. In boys, maturity status is the only determinant factor for body composition, because they have greater inter-individual variability for maturity status than for PA.

Our findings lead us to believe that PA level is a determinant factor for body composition changes only among adolescents with higher maturity status, and since PA seems to have a protective effect against adiposity, it is urgent to enforce prevention programs with school-age children that attempt to attenuate the decline in PA, even if PA levels cannot be increased, in order to improve adolescent health.

To go even further it is important to proceed with longitudinal investigations of this matter, verifying the existence of a cut-off value for PA in adolescents (at MVPA, MPA and VPA intensities), which places it as a major determinant factor in the body composition rather than the maturity status.

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