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Confounding effect of biologic maturation on sex differences in physical activity and sedentary behavior in adolescents

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**GENDER DIFFERENCES IN PHYSICAL ACTIVITY AND SEDENTARY
BEHAVIOUR IN PORTUGUESE YOUTH: IS BIOLOGICAL MATURATION A
CONFOUNDING FACTOR?**

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Running head:

Maturational effect on physical activity and sedentary habits of adolescents

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Abstract

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Introduction

The decline of physical activity from late childhood is well documented in males and females. This decline is particularly marked during the adolescence, the period of psychological and physical transition from youth to adulthood. Adolescence is recognized as a period of great physical, psychological, cognitive and emotional changes, which may be linked to physical activity, and influence adolescent participation in physical activity (Sallis et al., 2000).

Although declines in physical activity are evident in both genders, results from several investigations have shown adolescent males to be, on average, more physically active and more likely to engage in exercise than females of the same chronological age (Malina et al., 2004). Sex differences in physical activity are consistent across cultures and are independent of research design (i.e., cross-sectional or longitudinal) and methods used to assess physical activity (i.e., self-report instruments, accelerometry). An investigation of accelerometer-assessed physical activity in 2185 participants from the *European Youth Heart Study* revealed that 15-yrs-old boys spend 36% more time in daily moderate physical activity than their same age female peers (Riddoch et al., 2004). Similarly, evidence using a large sample youth from the United States (N = 4867) demonstrated that between 12-15 years-of age, boys were more likely to engage in moderate-to-vigorous physical activity than girls [boys: 41 minutes/day (non-hispanic white), 54 min/day (non-hispanic black), 51 min/day (Mexican-American); girls: 22 minutes/day (non-hispanic white), 26 min/day (non-hispanic black), 27 min/day (Mexican-American)] (Toiano et al., 2008).

Although sex differences in physical activity are well documented, studies rarely have considered the potential confounding effects sex related differences in maturational timing (Baxter Jones Paper on controlling for mat should be referenced here). In other words, most studies have compared boys and girls of the same chronological age without considering sex differences in biological age. Biological maturation is a factor that may contribute to sex differences in physical activity and refers to progress toward the mature state, which can be discussed in terms of variation in timing – when events occur, and tempo – rate (Malina et al., 2004; Beunen et al., 2006). Age for age, females are, on average, advanced in biological maturity status when compared to males. Indeed, girls generally enter puberty and reach adulthood two years in advance of boys. As physical activity in males and females decrease with chronological age, at least beyond the age of 7 years (Malina & Katzmarzyk, 2006), it is reasonable to assume that sex-differences in physical activity or sedentary behavior might be attributable to the fact that girls mature early than boys (Thompson et al., 2003). In support of this contention, Thompson and colleagues (2003) found that sex differences in self-reported physical activity were eliminated when adolescents were grouped by biological, rather than chronological age. Similarly, in a cohort of 186 British students (14.1 ± 0.3 years of age) Cumming and associates (2008) observed that existing sex differences in exercise behaviour were attenuated and nonsignificant when biological age was controlled for. Both of these studies utilized non-invasive estimates of maturity status (years before peak height velocity (PHV) and percentage of predicted mature height attained, respectively), and self-report measures of physical activity/exercise. Employing objective measures of physical activity and biological age, Sherar et al. (2007), in a sample of 401 Canadian boys and girls aged 8 to 13 years, reported that sex differences in moderate to vigorous forms of physical activity emerged when participants were aligned by chronological, but not biological (assessed by the years from attainment of PHV), age.

An issue of equal importance, that has received comparatively less attention, is potential sex differences in physical inactivity or sedentary behaviour. Exercise researchers often reported that being sedentary is associated with significant health risks but few studies to date have measured sedentary or low activity behaviour. For example, several important studies such as the *Harvard Alumni Study* or the *1999 Youth Risk Behaviour Survey* have report conclusions about the effect of sedentary behaviour on health without have actually measured such behaviour (Pate et al., 2008). In addition, to date, few self-report instruments were developed and even fewer were validated to assess light-intensities of physical activity and sedentary behaviour. Thus, recent advances of objective technological systems for measuring physical activity (such as accelerometry) allow monitoring a wide range of intensities of this complex multidimensional variable with considerable precision. Furthermore, it is common assumed in the literature that sedentary behavior increases through adolescence years. In a related British study, Murdey and colleagues (2005), in a sample of 83 school students aged 10-15 years, observed that sedentary habits have increased with changes in pubertal status (self-reported). However, this study did not examine the potential confounding effect of biologic maturity on sex differences in sedentary behavior.

To date, the available literature analyzing the impact of maturation on sex-related differences in physical activity and sedentary behaviour is limited, especially with the objective measures of physical activity and maturation,. In view of the limited amount of empirical research, the purpose of the present study is to examine the impact of biologic age on gender-related differences in sedentary, light and moderate-to-vigorous physical activity in Portuguese school adolescents aged from 13 to 16 years. Based on past, it was predicted that

(1) males would be more physically active than females, (2) females would spend more daily time in sedentary activities than their counterparts, (3) females would be biologically more mature than males of the same chronological age, (4) controlling for maturation would attenuate sex-related differences in sedentary, and moderate-to-vigorous physical activity.

Methods

Sample

The sample comprised 135 male and 167 female (14.2 ± 1.0 years of age) from seven schools in the Portuguese Midlands. The study was approved by the Scientific Committee of the University of Coimbra and prior to collection of data, consent to conduct the study was issued from the *Regional Education Office* which required the registration of the initiative in the *Portuguese Commission for Data Protection* [Process #3132006]. Parents were informed of the research by post, and asked to provide passive consent. Finally, written consent was obtained from both students and their parents.

Field Protocol

The first visit to schools always occurred in Wednesdays and was used to explain the study's purposes, collect anthropometric data, and to explain the usage and distribute the accelerometers devices. Participants were contacted at school Thursdays, Fridays and Mondays to ensure adequate usage of the accelerometer. These procedures for use of the instrument were explained to subjects in a classroom setting.

A second session, on the following Tuesday, was used to collect the instruments for analysis. All teachers were master's degree students in the *Faculty of Sports Sciences and Physical Education* at the *University of Coimbra* and were informed with regard to the research protocol.

Anthropometry

Height and weight were measured using a portable stadiometer (Harpender model 98.603, Holtain Ltd, Crosswell, UK) and a portable scale (Seca model 770, Hanover, MD, USA) to the nearest 0.1 cm and 0.1 kg, respectively, following Ross and Marfell-Jones procedures (Ross & Marfell-Jones, 1991). Technical errors of measurement (σ_e) and reliability coefficients (R) were calculated (conducted in a separate sample) as following: σ_e =0.34 cm, R=1.00 (height); σ_e =0.58 Kg, R= 1.00 (weight); σ_e =0.44 cm, R=0.99 (waist circumference); σ_e =0.71 Kg, R=0.97 (triceps skinfold); σ_e =0.30 cm, R=0.98 (biceps skinfold); σ_e =0.73 Kg, R=0.94 (subscapular skinfold); σ_e =0.92 cm, R=0.98 (suprailiac skinfold); σ_e =0.85 Kg, R=0.96 (abdominal skinfold); σ_e =0.76 Kg, R=0.97 (medial-calf skinfold). The body mass index (BMI, Kg/m²) was calculated.

Physical activity and sedentary habits

Physical activity and sedentary habits levels were directly measured for five consecutive days, using the ActiGraph GT1M accelerometer (ActiGraphTM, LLC, Fort Walton Beach, FL, USA). This activity monitor is a uniaxial accelerometer designed to detect vertical accelerations ranges in magnitude from 0.05 to 2.00g with a frequency of response of 0.25-2.50 Hz that allow normal human motion assessment. The ActiGraph (previously known as MTI and CSA) accelerometer is a compact, small (3.8 cm x 3.7 cm x

1.8 cm), lightweight (27g) and has been widely validated in laboratory and free-living conditions with children and adolescents (Freedson et al., 2005).

Participants wore the motion sensor over the hip firmly placed with an elastic belt, and were instructed to remove the monitor while showering and swimming activities. On completion of data collection, the data were electronically downloaded (using the MAHUFFe program, www.mrc-epid.cam.ac.uk), resulting in a file containing minute-by-minute movement counts for each adolescent. Files with a incomplete data were removed (i.e. if they failed to provide a minimum of 600 minutes of valid accelerometer data after removing sequences of 10 or more consecutive zero counts). A more complete description of data-reduction procedures can be found elsewhere (Riddoch et al., 2004; Esliger et al., 2005).

Sedentary habits were obtained using the regressions for adolescents proposed by Puyau et al. (2002). In addition, moderate, vigorous and very vigorous activities were estimated using the equations for children and adolescents, age-specific criteria of the Freedson group, as published by Trost et al. (2002). These cut-points have been used in several youth epidemiological studies (Riddoch et al., 2004; Troiano et al., 2008). The total amount of sedentary habits and moderate-to-very vigorous physical activity was expressed in minutes. The output also included the mean daily time registered on week days and weekend.

Maturity status

The percentage of adult height attained at the time measurement was used as a non-invasive estimate of biological maturity status. This method assumes that among youth of the same chronological age, the individual who is closer to his/her predicted mature height is

biological older (i.e., more advanced in maturity) than individual who is further removed from his/her predicted adult height than expected for age (Malina, Bouchard & Bar-Or, 2004).

The Khamis-Roche method was used to predict height from the current age, height, and weight of the participants and midparent height (average height of biological parents). The mean error bound (median absolute deviation) between actual and predicted mature height at 18 years of age is 2.2 cm in males and 1.7 cm in females (Khamis & Roche, 1994). Biological parents of the students reported their heights. As adults tend to overestimate height (Epstein et al., 1995), the self-reported height of each parent was adjusted for overestimation using an equation constructed from over 1000 measured and estimated heights of adults (Epstein et al., 1995).

Data Analysis

Participants were divided into two age groups (13-14 years and 15-16 years) so as to examine any effect that age might have on maturity associated variance in active and sedentary behaviours. Chronological age in decimals was calculated as the difference between date of birth and date of measurements. Descriptive statistics were calculated for age, body mass, percentage of predicted mature height, physical activity in its different portions of intensity and sedentary behavior, separately for boys and girls. Sex-specific Pearson product moment correlations (one tailed) were determined between chronological age, height, weight, waist circumference, sum of skinfolds, BMI, predicted mature height, sedentary habits and total of moderate-to-very vigorous physical activity. To investigate sex-related differences in sedentary and physical activity behaviors multivariate analyses of variance (MANOVA) were used. In addition, multivariate analyses of covariance (MANCOVA) were used to examine

sex-related differences in sedentary habits and physical activity, controlling for biological age (i.e., percentage of predicted adult stature attained at measurement).

Results

Sex differences in sedentary and physical activity behaviors

Descriptive statistics for chronological age, all indices of body size, biological maturity, and sedentary habits and physical activity measures are summarized by sex and age group in Table 1.

[Table 1]

A one-way between-groups multivariate analysis of variance was performed to investigate sex differences in sedentary habits on week days, weekend and total of days assessed. Results showed a significant main effect for gender in sedentary behaviour for both age-groups ($F_{(3,182)}=5.17$, $p=.002$, $\eta^2=0.08$ and $F_{(3,112)}=2.83$, $p=.042$, $\eta^2=0.07$, respectively for 13-14 and 15-16 age-groups). When the results for the dependent variables were considered separately, the only difference to reach statistical significance on 13-14 years age-group, using a Bonferroni adjustment alpha level of .017, was on week days ($F_{(1,184)}=11.43$, $p=.001$, $\eta^2=0.06$). Follow-up the univariate *F-tests* for older age-groups showed that males have less sedentary habits than females not only on week days ($F_{(1,114)}=4.22$, $p=.042$, $\eta^2=0.04$), but also on weekend ($F_{(1,114)}=6.90$, $p<0.01$, $\eta^2=0.06$), and in the total of five days measured ($F_{(1,114)}=7.80$, $p<0.006$, $\eta^2=0.06$). However, males and females did not differ in light physical activity, neither among younger or older age-groups ($F_{(3,182)}=0.26$, $p<0.852$, $\eta^2=0.00$

and $F_{(3,112)}=2.45$, $p<0.006$, $\eta^2=0.06$, respectively). In addition, results of the MANOVA showed there was a statistically significant difference between gender for moderate-to-vigorous physical activity in both age-groups ($F_{(3,182)}=13.44$, $p<0.000$, $\eta^2=0.18$ for 13-14 years age-group, and $F_{(3,112)}=3.68$, $p<0.014$, $\eta^2=0.09$ for 15-16 years age-group).

Results of the MANCOVA, controlling for biologic maturity, did not show a significant main effect for sex in terms of sedentary behaviours ($F_{(3,181)}=2.48$, $p<0.063$, $\eta^2=0.04$ for 13-14 years age-group; $F_{(3,111)}=2.47$, $p<0.066$, $\eta^2=0.06$ for 15-16 years age-group) and moderate-to-vigorous physical activity ($F_{(3,181)}=2.47$, $p<0.063$, $\eta^2=0.04$ and $F_{(3,111)}=2.19$, $p<0.093$, $\eta^2=0.06$ for younger or older age-groups, respectively) for both different age groups. When we analyze the sex differences for light physical activity, separately for age-groups, we did not found any significant gender effect for younger age-group ($F_{(3,181)}=0.07$, $p<0.977$, $\eta^2=0.00$). However, MANCOVA analysis shows a significant main effect for sex in light physical activity of 15-16 years age-group, after controlling for biologic maturity ($F_{(3,112)}=3.68$, $p<0.014$, $\eta^2=0.09$). Follow-up the univariate *F-tests* for older age-groups showed that males have more light physical activity than their counterparts on week days ($F_{(1,114)}=4.79$, $p=.031$, $\eta^2=0.04$), at the weekend ($F_{(1,114)}=13.78$, $p<0.000$, $\eta^2=0.11$), and in the total of five days measured ($F_{(1,114)}=11.24$, $p<0.001$, $\eta^2=0.09$).

Correlates of biological maturity and body size

Relations between chronological age, biological maturity, indices of body size, and sedentary behaviour and physical activity are presented in Table 2 and 3 for males (13-14 years age-group and 15-16 years age-group, respectively), and Table 4 and Table 5 for females (younger age-group and older age-group, respectively).

As expected, advanced biological maturity was significantly correlated with greater weight, height, in both males and females and for both 13-14 and 15-16 years age-groups. In addition, the same relationship was found on the weight for height, with 15-16 years boys' age-group exception.

Table 1. Descriptive statistics for chronological age, current and predicted body size, percentage of predicted mature height attained at measurement, and objective sedentary habits and physical activity measures, by sex and age-group.

	Males (n=135)				Females (n=167)			
	13-14 yrs age-group (n=81)		15-16 yrs age-group (n=54)		13-14 yrs age-group (n=105)		15-16 yrs age-group (n=62)	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Chronological age, years	13.5	0.6	15.3	0.6	13.4	0.6	15.2	0.5
Height, cm	160.7	9.6	171.2	7.4	157.2	6.2	159.2	5.4
Weight, Kg	51.1	11.5	63.1	10.1	51.7	9.7	55.0	9.3
Waist circumference, cm	73.6	8.8	78.5	7.1	75.8	8.6	77.6	6.7
Sum of six skinfolds, mm	63.4	37.5	54.5	35.1	87.2	34.0	84.6	23.1
BMI, Kg/m ²	19.56	3.17	21.55	3.44	20.89	3.56	21.64	3.13
Predicted mature height, cm	175.1	7.0	175.8	6.1	162.0	5.0	160.6	5.3
Percentage of predicted mature height attained	91.8	3.6	97.4	1.8	97.0	2.0	99.1	0.5
SEDh (week days), min	704.5	68.3	733.3	55.2	738.3	67.0	753.4	50.2
SEDh (weekend), min	662.3	88.8	663.0	71.5	650.8	71.7	701.3	83.8
SEDh (total of 5 days), min	687.5	60.9	705.1	52.7	703.2	55.3	732.4	52.5
Light PA (week days), min	64.2	19.1	74.5	22.3	64.2	24.2	68.4	22.6
Light PA (weekend), min	64.6	29.1	72.2	30.9	61.9	29.1	58.5	24.6
Light PA (total of 5 days), min	64.2	20.0	73.5	21.7	63.2	24.7	64.3	20.7
MVPA (week days), min	109.5	39.8	70.7	29.0	78.6	27.3	60.0	26.6
MVPA (weekend), min	67.7	39.4	49.7	33.3	47.3	30.5	32.5	23.8
MVPA (total of 5 days), min	92.6	33.4	62.3	25.0	66.1	25.5	48.9	22.6

SEDh (Sedentary habits); PA (Physical Activity); MVPA (Moderate to Vigorous Physical Activity).

Table 2. Pearson product moment correlations (one tailed) between measures of chronological age, biological age, body size, sedentary behaviour and physical activity in males (13-14 years age-group).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Chronological age															
2. Ppmha	.73**														
3. Heigh	.42**	.75**													
4. Weight	.29**	.63**	.73**												
5. Waist circumference	.20*	.44**	.49**	.90**											
6. Sum skinfolds	-.08	.06	.03	.61**	.80**										
7. BMI	.10	.34**	.30**	.87**	.90**	.83**									
8. SED week	.16	.16	.10	.09	.05	.00	.08								
9. SED weekend	.21*	.23*	.15	.03	-.04	-.10	-.05	.26**							
10. SED total	.23*	.24*	.15	.08	.01	-.06	.02	.83**	.76**						
11. Light PA week	-.16	-.13	-.11	.02	.09	.09	.10	-.32**	-.20*	-.33**					
12. Light PA Weekend	-.11	-.21*	-.18	-.09	-.04	-.02	.00	-.31**	-.53**	-.52**	.50**				
13. Light PA total	-.16	-.20*	-.17	-.04	.03	.04	.06	-.36**	-.43**	-.49**	.86**	.87**			
14. MVPA week	-.33**	-.33**	-.21*	-.23*	-.23*	-.12	-.16	-.50**	-.09	-.39**	.44**	.18	.35**		
15. MVPA weekend	-.26**	-.43**	-.37**	-.36**	-.30**	-.16	-.25*	-.46**	-.56**	-.64**	.22*	.66**	.51**	.39**	
16. MVPA total	-.36**	-.44**	-.32*	-.33**	-.30**	-.16	-.24*	-.57**	-.33**	-.58**	.42**	.44**	.49**	.90**	.75**

Ppmha (Percentage of predicted mature height attained); SED (Sedentary behaviour); PA (Physical Activity); MVPA (Moderate-to-Vigorous Physical Activity).

Table 3. Pearson product moment correlations (one tailed) between measures of chronological age, biological age, body size, sedentary behaviour and physical activity in males (15-16 years age-group).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Chronological age															
2. Ppmha	.58**														
3. Heigh	.20	.63**													
4. Weight	.01	.27*	.36**												
5. Waist circumference	-.07	.07	.06	.90**											
6. Sum skinfolds	-.22	-.12	-.22	.71**	.85**										
7. BMI	-.12	-.07	-.19	.84**	.91**	.89**									
8. SED week	.05	-.11	-.37**	-.11	-.05	.03	.10								
9. SED weekend	-.04	-.12	-.09	-.03	-.06	-.08	.00	.46**							
10. SED total	.01	-.13	-.28*	-.09	-.07	-.03	.06	.88**	.83**						
11. Light PA week	.30*	.26*	.05	.19	.17	.19	.18	-.29*	-.30*	-.34**					
12. Light PA Weekend	.52**	.34**	.03	-.02	-.05	.02	-.03	.00	-.13	-.07	.42**				
13. Light PA total	.48**	.35**	.04	.11	.08	.13	.09	-.18	-.26*	-.25*	.86**	.83**			
14. MVPA week	-.23	-.03	.11	.07	.11	.01	.00	-.42**	-.31*	-.43**	.25*	-.19	.05		
15. MVPA weekend	-.01	-.00	-.05	.11	.22	.28*	.16	-.08	-.36**	-.25*	.13	.39**	.31*	.31*	
16. MVPA total	-.16	-.02	.05	.11	.20	.16	.09	-.34**	-.41**	-.43**	.25*	.08	.20	.86**	.75**

Ppmha (Percentage of predicted mature height attained); SED (Sedentary behaviour); PA (Physical Activity); MVPA (Moderate-to-Vigorous Physical Activity).

Table 4. Pearson product moment correlations (one tailed) between measures of chronological age, biological age, body size, sedentary behaviour and physical activity in females (13-14 years age-group).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Chronological age															
2. Ppmha	.50**														
3. Heigh	.21*	.63**													
4. Weight	.11	.77**	.44**												
5. Waist circumference	.11	.65**	.25**	.87**											
6. Sum skinfolds	-.17*	.42**	.05	.80**	.78**										
7. BMI	.04	.58**	.05	.91**	.87**	.87**									
8. SED week	.19*	.03	-.02	-.12	-.20*	-.10	-.14								
9. SED weekend	.14	-.07	-.07	-.11	-.14	-.09	-.09	.26**							
10. SED total	.21*	-.01	-.06	-.15	-.22*	-.12	-.15	.87**	.71**						
11. Light PA week	.18*	.14	.05	.08	.19*	-.01	.07	-.23**	-.35**	-.35**					
12. Light PA Weekend	.02	.08	-.02	.14	.25**	-.09	.16	-.28**	-.39**	-.41**	.78**				
13. Light PA total	.12	.12	.02	.11	.23**	.04	.12	-.27**	-.39**	-.40**	.96**	.93**			
14. MVPA week	-.30**	-.01	-.02	.19*	.15	.23**	.22*	-.42**	-.28**	-.46**	.31**	.34**	.34**		
15. MVPA weekend	-.22*	.03	.00	.16	.12	.15	.18*	-.27**	-.45**	-.43**	.29**	.55**	.43**	.59**	
16. MVPA total	-.30**	.01	-.01	.20*	.16	.22*	.23*	-.40**	-.40**	-.50**	.34**	.48**	.43**	.92**	.86**

Ppmha (Percentage of predicted mature height attained); SED (Sedentary behaviour); PA (Physical Activity); MVPA (Moderate-to-Vigorous Physical Activity).

Table 5. Pearson product moment correlations (one tailed) between measures of chronological age, biological age, body size, sedentary behaviour and physical activity in females (15-16 years age-group).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Chronological age															
2. Ppmha	.51**														
3. Heigh	.28	.25*													
4. Weight	.04	.56**	.48**												
5. Waist circumference	.03	.52**	.50**	.95**											
6. Sum skinfolds	-.10	.18	.06	.70**	.65**										
7. BMI	.02	.52**	.09	.92**	.85**	.77**									
8. SED week	.04	-.08	-.04	-.16	-.14	-.22*	-.15								
9. SED weekend	.16	.26*	.04	-.04	-.05	-.19	-.06	.36**							
10. SED total	.13	.12	.00	-.12	-.11	-.25*	-.12	.80**	.85**						
11. Light PA week	.22*	-.02	.04	-.16	-.19	-.04	-.20	-.45**	-.09	-.32**					
12. Light PA Weekend	.11	-.03	.02	-.08	-.13	-.06	-.09	-.12	-.05	-.10	.55**				
13. Light PA total	.20	-.03	.04	-.14	-.18	-.05	-.18	-.35**	-.08	-.25*	.92**	.84**			
14. MVPA week	-.08	-.11	.17	.11	.11	.13	.04	-.53**	-.30**	-.49**	.49**	.30**	.46**		
15. MVPA weekend	-.22*	-.17	.25*	.14	.15	.14	.06	-.15	-.39**	-.33**	.15	.50**	.34**	.54**	
16. MVPA total	-.15	-.15	.23*	.14	.14	.15	.06	-.44**	-.38**	-.49**	.41**	.42**	.47**	.93**	.81**

Ppmha (Percentage of predicted mature height attained); SED (Sedentary behaviour); PA (Physical Activity); MVPA (Moderate-to-Vigorous Physical Activity).