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Confounding Effect of Biologic Maturation on Sex Differences in Physical Activity and Sedentary Behavior in Adolescents

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Sex differences in physical activity (PA) through pubertal maturation and the growth spurt are often attributed to changing interests. The contribution of sex differences in biological maturation to the adolescent decline has received limited attention. This study examined the contribution of somatic maturation to sex differences in objective assessments of sedentary behavior and PA in Portuguese adolescents ($N = 302$, aged 13–16 years). Maturation was estimated from the percentage of predicted mature stature and physically active and inactive behaviors assessed with Actigraph GT1M accelerometers. The influence of age, sex and their interaction on body size, maturation and physical behaviors were examined using factorial ANOVA and, subsequently, ANCOVA (controlling for maturation) tested the effect of sex. Males spent more time in MVPA and less time in sedentary behavior than females. However, sex differences were attenuated when maturation was controlled; thus suggesting that maturity may play an important role in adolescent behaviors.

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From the perspective of public health, physical activity is defined as "any bodily movement produced by skeletal muscles that results in a substantial increase in energy expenditure above resting metabolic rate and includes leisure time physical activity, exercise, sport, occupational work, and household and other chores" (5). Habitual physical activity, on the other hand, is a complex behavior that is influenced by interactions between biological and psychosocial characteristics of the individual and the physical and social environments in which the adolescent lives. Although daily energy expenditure and activity energy expenditure decline with age from early childhood onward, level of physical activity is generally stable during childhood but declines with the transition into adolescence and continues through the period of physical, physiological and psychological transition into adulthood (15).

Boys, on average, are more physically active than girls during childhood and through adolescence. The sex difference is generally attributed to differences in rearing, social expectations and other cultural factors. However, sex differences in estimated maturity status accounts for a small but significant portion of the variation in activity level in children 5–9 years of age (8). Sex differences in activity at older ages may also be influenced by maturity status, especially in the context of the earlier growth spurt and sexual maturation in girls compared with boys (15). Most studies comparing physical activity in boys and girls focus on chronological age to the exclusion of differences in the timing of maturation (3). It is thus not unreasonable to assume that sex differences in biological maturation may contribute to sex-differences in physical activity, especially during adolescent years. Given the variation in the timing of the growth spurt and sexual maturation, one may expect that sex differences in physical activity would be attenuated when maturation is controlled for in statistical analyses. This was indeed noted in surveys of physical activity based on questionnaires among Canadian (31) and British adolescents (7) and based on objective assessment of physical activity in Canadian youth 8–13 years (29).

Assessment of maturity status is a potentially important factor in studies of youth in the transition into and during adolescence. Indicators commonly used in growth studies tend to be invasive, e.g., skeletal and sexual maturation, or require longitudinal data, e.g., age at peak height velocity (15). Self-assessment of pubertal status is commonly used, but in some cultures this too may be considered invasive. Stages of puberty, though valuable, are also limited in the information provided. They simply indicate the stage of puberty and provide no indication of when the youngster entered the stage or how long he/she has been in the stage. Moreover, youth in the same stage of puberty but of different chronological ages are confounded by age, per se. A protocol for the estimation of age at peak height velocity is also available (19) and increasingly used in studies of physical activity (29,35). An alternative maturity indicator is the percentage of predicted mature stature attained at a given age (14). Two children may have the same height at a given chronological age, but one may have already attained a greater percentage of mature height than the other and is, therefore, closer to mature state (15). Percentage of predicted mature stature has been used in a study focused on sex differences in leisure-time activity assessed by questionnaire (7) and also as a risk factor for injury in youth sport (16,17).

Studies of the effects of sedentary and physically active behaviors on health outcomes should be supported by evidence in which all levels of activity are differentiated clearly and measured independently (22). Research pertaining to sex differences sedentary behavior is not as abundant as for physical activity. Results from a large cohort of British youth demonstrated that girls tend to be more sedentary than boys and that sex differences were especially evident on weekdays (20,25). To date, the potential confounding effect of maturation on sex differences in sedentary behavior has not been addressed during the pubertal years. In one of the few studies that included measures of sedentary behavior and biological maturation, sedentary habits increased with stage of self-reported (questionnaire) pubertal status between 10 and 15 years (21).

Given the limited research examining the role of maturation relative to sex differences in physically activity and inactive behaviors, the purpose of the current study was to examine the contribution of somatic maturation, given by the percentage of estimated mature stature attained at a given age, to sex differences in objective assessment of sedentary behavior and physical activity in adolescents.

Methods

The sample included 135 males and 167 females (14.2 ± 1.0 years) from seven schools in the Portuguese Midlands. The study was approved by the Scientific Committee of the University of Coimbra and the Regional Education Office, which required registration of the study in the Portuguese Commission for the Protection of Personal Data [Process #3132006]. Written consent was obtained from both parents and students.

Height and weight were measured using a portable stadiometer (Harpenden 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.

Percentage of predicted mature (adult) height attained at the time measurement was used as an estimate of biological maturity status. The method assumes that among youth of the same chronological age, individuals closer to predicted mature height are advanced in biological maturation compared with individuals who are further from predicted mature height (15). The Khamis-Roche method (14) was used to predict mature height from current age, height and weight of the adolescent 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 was 2.2 cm in males and 1.7 cm in females (14).

Physical activity and sedentary behavior were measured for five consecutive days using an ActiGraph GT1M accelerometer (ActiGraph, LLC, Fort Walton Beach, FL, USA). Subjects were instructed to remove the sensor while showering or participating in swimming activities. The uniaxial accelerometer was designed to detect vertical accelerations ranging in magnitude from 0.05 to 2.00g with a frequency of response of 0.25–2.50 Hz that allows assessment of normal human motion. The ActiGraph uniaxial accelerometer (previously known as MTI 7164 model and CSA) is compact (3.8 cm × 3.7 cm × 1.8 cm) and light (27g) and has been validated in laboratory and free-living children and adolescents (9). It was recently reported that counts measured by GT1M were slightly lower (about 9%) than using the previous MTI 7164 model (6,28). The data were electronically downloaded using the ActiLife software. The MAHUffe program was used to reduce the data in a file containing minute-by-minute counts. Participants who did not have 10 hr of valid measured data for each of the five days were excluded from subsequent analyses. The threshold of sedentary activity (minimal body movements in the sitting or reclining position) was established at 800 counts.min^{-1} (23) and intensity levels of physical activity were determined using age-specific regression equation (10) that were published by (34) with thresholds at 4 and 7 METS, respectively for moderate and vigorous activities (32). This adjusts for the higher resting energy expenditure of children and youth (26). These criteria have been previously used in epidemiological studies of youth (24,32).

Chronological age was calculated as the difference between date of birth and date of measurements. Participants were divided in two groups, 13–14 and 15–16 years. Factorial analyses of variance were used to examine the effect of age, sex and their interaction in height, weight, percentage of predicted mature stature attained as the time of study, and minutes spent in each category of physical activity and sedentary behavior. Subsequently, analyses of covariance, controlling for estimated maturity status, were conducted to determine whether sex differences in sedentary and physically active behaviors were attenuated. Statistical significance was set at 5%. In addition, multiple linear regression (backward elimination method with the stepping criteria for removal of $p < .10$) was used to estimate the contribution of chronological age, height, weight, and percentage of estimated mature height to variation in each intensity level of physically active behaviors. This process reduces collinearity among independent variables in the final regression model by eliminating those variables do not predict a significant propotion of variance in the outcome measures.

Results

Descriptive statistics by age and sex are summarized in Table 1. As expected, chronological age, sex and their interaction had a significant effect on body size. With few exceptions, minutes in sedentary behaviors and physical activities of two intensities were significantly affected by chronological age, sex and their interaction.

In the younger group, girls were, on average, 3.7 cm shorter than boys but did not differ in body mass. In contrast, older boys were, on average, 12.0 cm taller and 8.1 kg heavier than females. Percentage of predicted mature stature attained at the time of study was significantly affected by age [$F_{(1,302)}$=187.83, $p < .01$ $\eta^2 = 0.39$], sex [$F_{(1,302)}$=155.14, $p < .01$ $h^2 = 0.34$] and the age x sex interaction [$F_{(1,302)}$=38.72, $p < .01$ $\eta^2 = 0.12$].

The results of the factorial ANOVA revealed a significant main effect of sex in sedentary behavior for the five days [$F_{(1,302)}$=10.50, $p < .01$, $h^2 = 0.03$]. Compared with boys, girls spent more time in sedentary activities. The sex-related variation in sedentary behavior was more evident during weekdays in the younger group, but on weekend days in the older group. However, the main effect of sex on sedentary behavior was attenuated and nonsignificant when biological maturation was statistically controlled (Table 2).

Significant main effects for sex in LPA were observed for the five consecutive days [$F_{(1,302)}$=3.80, $p < .05$, $\eta^2 = 0.01$] in part due to significant differences on weekends [$F_{(1,302)}$=5.80, $p < .05$, $h^2 = 0.02$]; no differences were noted for weekdays. Among 13–14 year old youth, boys spent more than 2.7 min per day in LPA during weekends than girls. The corresponding sex difference in the older group was 13.7

Table 1 Means (SD) for Chronological Age, Percentage of Predicted Mature Height, Body Size, and Time Spent in Sedentary Behaviors and in Physical Activities by Age Group and Sex

	13–14 years		15–16 years		Effect of age		Effect of sex		Effect of age x sex	
	Males (n = 81)	Females (n = 105)	Males (n = 54)	Females (n = 62)	F (p)	η^2	F (p)	η^2	F (p)	η^2
Chronological age, years	13.5 (0.6)	13.4 (0.6)	15.3 (0.6)	15.2 (0.5)						
Percentage of mature height, %	91.8 (3.6)	97.0 (2.0)	97.4 (1.8)	99.1 (0.5)	187.83 (.00)	.39	155.14 (.00)	.34	38.72 (.00)	.12
Height, cm	160.9 (9.6)	157.2 (6.2)	171.2 (7.4)	159.2 (5.4)	50.06 (.00)	.14	81.25 (.00)	.21	23.19 (.00)	.07
Weight, Kg	51.1 (11.5)	51.7 (9.7)	63.1 (10.1)	55.0 (9.3)	39.49 (.00)	.12	9.68 (.00)	.03	13.19 (.00)	.04
SED (week days), min	704.5 (68.3)	738.3 (67.1)	733.3 (55.2)	753.4 (50.2)	8.76 (.00)	.03	13.26 (.00)	.04	0.85 (.36)	.00
SED (weekend), min	662.3 (88.8)	650.8 (71.7)	663.0 (71.5)	701.3 (83.8)	7.39 (.01)	.02	2.03 (.16)	.01	7.03 (.01)	.02
SED (total of 5 days), min	687.5 (60.9)	703.2 (55.3)	705.1 (52.7)	732.4 (52.5)	12.38 (.00)	.04	10.50 (.00)	.03	0.77 (.38)	.00
Light PA (week days), min	64.2 (19.1)	64.2 (24.2)	74.5 (22.3)	68.4 (22.6)	7.54 (.01)	.03	1.35 (.25)	.00	1.35 (.25)	.01
Light PA (weekend), min	64.6 (29.1)	61.9 (29.2)	72.2 (30.9)	58.5 (24.6)	.38 (.54)	.00	5.80 (.02)	.02	2.59 (.11)	.01
Light PA (total of 5 days), min	64.2 (20.1)	63.2 (24.7)	73.5 (21.7)	64.3 (20.7)	3.90 (.05)	.01	3.80 (.05)	.01	2.38 (.12)	.01
MVPA (week days), min	109.5 (39.8)	78.6 (27.3)	70.7 (30.0)	60.0 (26.6)	59.50 (.00)	.17	31.21 (.00)	.10	7.29 (.01)	.02
MVPA (weekend), min	67.7 (39.4)	47.3 (30.5)	49.7 (33.3)	32.5 (23.8)	18.07 (.00)	.06	23.68 (.00)	.07	0.16 (.69)	.00
MVPA (total of 5 days), min	92.6 (33.4)	66.1 (25.5)	62.3 (25.0)	48.9 (22.6)	53.89 (.00)	.15	38.08 (.00)	.11	4.16 (.04)	.01

Note. SED (minutes spent sedentary); PA (Physical Activity); MVPA (Moderate to Vigorous Physical Activity).

Table 2 Adjusted Means (and Standard Errors) and Results of Analyses of Covariance (Maturity Status as the Covariate) to Test the Effect of Sex on Time Spent in Sedentary Behaviors and Physical Activities of Different Intensities

	13–14 years		15–16 years		F (p)	η^2
	Males (n = 81)	Females (n = 105)	Males (n = 54)	Females (n = 62)		
SED (week days), min	711.7 (9.1)	732.8 (7.7)	729.9 (8.0)	756.4 (7.4)	5.21 (.02)	.02
SED (weekend), min	671.9 (10.7)	643.4 (9.1)	662.4 (12.0)	701.7 (11.0)	0.09 (.76)	.00
SED (total of 5 days), min	695.7 (7.8)	696.9 (6.6)	702.8 (8.0)	734.3 (7.4)	2.88 (.09)	.01
Light PA (week days), min	64.1 (3.0)	64.2 (2.5)	77.1 (3.4)	66.1 (3.1)	1.59 (.21)	.01
Light PA (weekend), min	61.9 (3.9)	63.9 (3.3)	77.0 (4.1)	54.3 (3.8)	3.10 (.08)	.01
Light PA (total of 5 days), min	63.1 (3.1)	64.0 (2.6)	77.0 (3.2)	61.3 (2.9)	2.79 (.10)	.01
MVPA (week days), min	101.8 (4.4)	84.6 (3.7)	69.8 (4.2)	60.8 (3.9)	7.49 (.01)	.03
MVPA (weekend), min	58.4 (4.5)	54.5 (3.8)	49.0 (4.4)	33.1 (4.0)	3.50 (.06)	.01
MVPA (total of 5 days), min	84.3 (3.8)	72.5 (3.2)	61.5 (3.6)	49.6 (3.3)	7.85 (.01)	.03

Note. SED (minutes spent sedentary); PA (Physical Activity); MVPA (Moderate to Vigorous Physical Activity).

min. After controlling for differences in maturity status, sex differences were no longer significant for either weekdays or weekend days.

A significant main effect of sex of the individual on MVPA was observed on weekdays [$F_{(1,302)}$=31.21, $p < .01$, $\eta^2 = 0.10$], weekend days [$F_{(1,302)}$=23.68, $p < .01$, $\eta^2 = 0.07$] and consequently all days [$F_{(1,302)}$=38.08, $p < .01$, $\eta^2 = 0.11$]. The age x sex interaction also produced a significant effect for weekdays [$F_{(1,302)}$=7.29, $p < .01$, $\eta^2 = 0.02$] and total days [$F_{(1,302)}$=4.16, $p < .05$, $\eta^2 = 0.01$]. Results of factorial analyses of covariance (Table 2) suggested that the sex differences were no longer significant for weekend days and that the effect size was attenuated for the other days [weekdays: $F_{(1,302)}$=7.49, $p < .01$, $\eta^2 = 0.03$; all days: $F_{(1,302)}$=7.85, $p < .01$, $\eta^2 = 0.03$].

Results of the regression analyses are summarized in Table 3. The predictor variables explained 5–12% of the variance in sedentary behavior, 0–8% in LPA and 20–30% in MVPA. Chronological age was a significant predictor for LPA and MVPA in males, while age and body mass were significant predictors of the variance in sedentary behavior and MVPA in females. Percentage of predicted mature stature attained at the time of study was a significant predictor sedentary behavior, LPA and MVPA in boys but not in girls. The direction of the standardized coefficients for maturation was positive for sedentary behavior and negative for physical activity.

Discussion

The results are largely consistent with previous research (7,8,29,31) identifying biological maturation as a source of variation in sex differences in physical activity and sedentary behavior during adolescence. The use of percentage of predicted mature stature attained at the time of study as an indicator of maturity status and the objective assessment of sedentary behaviors are unique contributions in the study. The observations are particularly relevant as the decline in physical activity becomes more marked as adolescence progresses. Longitudinal data indicate that correlations between maturity indicators which occur closer in time during adolescence were higher than those more separated in time (11). Consequently, as adolescent growth proceeded skeletal age was more strongly related to percentage of mature stature than years from peak height velocity (15).

Predicted mature height as used in the current study has a limitation. It was based on an equation developed for a middle class of American youth in the Fels Longitudinal Study. The validation of the age- and sex-prediction equations for Portuguese youth needs to be examined.

Mean time spent in MVPA decreased by 28.8 and 18.6 min.day^{-1}, respectively, in boys and girls, from the younger to the older adolescent age groups. On the other hand, average daily time spent in sedentary behaviors increased with age in boys by 28.8 min.day^{-1} and in girls 15.1 min.day^{-1}. The cross-sectional design did not permit individuals to be followed as they progressed through adolescence. Nevertheless, the results were consistent with other cross-sectional data (27). Reported pedometer steps per day were greater among boys in stage 1 (10,509 steps.day^{-1}) than in stage 5 (8,103 steps.day^{-1}) of puberty. However, subjects in stage 5 were chronologically older so that the difference in physical activity could have been age- rather than maturity-related. The influence of biological maturity status on physical activity were also examined in longitudinal samples of 70 boys and 68

Table 3 Significant Predictors of Sedentary Behavior and Physical Activities of Different Intensities by Sex

Group	Behavior	R^2	Adjusted R^2	Model	Predictor	Unstandardized coefficients		95% CI for Beta		Standardized beta coefficient
						Beta	St. error	Lower	Upper	
Males	Sedentary	5%	4%	$F_{(1,133)}=6.207$; $p<.01$	% EMS	3.03	1.22	0.63	5.44	+0.21
	LPA	8%	6%	$F_{(2,132)}=5.353$; $p<.01$	CA	9.32	3.09	3.20	15.44	+0.46
					% EMS	-1.45	0.80	-3.03	-0.13	-0.28
	MVPA	30%	30%	$F_{(2,132)}=28.132$; $p<.01$	CA	-7.90	4.29	-16.39	-0.58	-0.46
					% EMS	-2.70	1.10	-4.89	-0.52	-0.33
Females	Sedentary	12%	11%	$F_{(2,164)}=10.750$; $p<.01$	CA	17.92	4.01	10.01	25.83	+0.33
					Body mass	0.88	0.42	0.02	1.72	+0.15
	LPA	-	-	-	-	-	-	-	-	-
	MVPA	20%	19%	$F_{(2,164)}=19.962$; $p<.01$	CA	-10.76	1.76	-14.23	-7.28	-0.44
					Body mass	-0.51	0.19	-0.89	-0.14	-0.19

Note. LPA (light physical activity); MVPA (moderate to vigorous physical activity); %EMS (percentage of estimated mature stature); CA (chronological age) girls 9–18 years (31). Although physical activity declined when plotted relative to both chronological and biological ages, the significant sex differences observed with chronological age were eliminated when the data were aligned by years before and after peak height velocity. Of note, both studies that examined maturity-related variation were not based on objectively assessed physical activity or activities of different intensities.

In general, boys spent more time in MVPA than girls. The sex difference in this level of physical activity was consistent with previous research using accelerometry with youth spanning the adolescent years (18,24,32). However, individual differences in maturity status were not considered in these studies. In a study that included an indicator of maturity status, level of PA decreased with increasing chronological age in both sexes 8–13 years and boys had higher MVPA at 10–13 yr; however, when aligned on biological age, sex differences disappeared (29).

Not all studies show a decline in physical activity across adolescence. In a large sample of Portuguese youth 10–18 years, school- and sport-related activities (Baecke questionnaire) declined in females only after 16 years while both school- and sport-related physical activities increased with age in males (30). Of relevance, Portuguese national statistics also showed that more males than females participated in organized sports (1,12). Among Canadian youth, organized sport participation appeared to be a significant component of daily energy expenditure (DEE); males expended 20.4% of DEE in organized sports compared with 16.3% in females (13).

The observation that sex differences in biological maturation influence sex differences in physical activity adds to our understanding of adolescent variation (7,29). Of interest, early-maturing youth had higher rates of both sedentary behaviors and vigorous physical activity than their "on-time" or average peers. The combination of higher rates of vigorous activity and sedentary behavior though seemingly contradictory, highlights the independence of physical activity and inactivity (4) and the need for further assessment of sedentary behaviors among youth.

Differences between males and females tend to be less marked in light forms of physical activity (29,33). Results of the current study also suggest that girls spent significantly more time in sedentary behaviors than boys, especially on weekdays. The tendency also surfaced on weekends but only in the older group. Of relevance, observations of immediate after school hours noted that technology-based sedentary behavior was higher in boys than girls (2).

Although differences in the timing and tempo of biological maturation may contribute to sex differences in physically active and sedentary behaviors, it is likely that a combination of the social, psychological, physical and physiological changes associated with biological maturation rather than maturity status per se underlie the observations. In the current study, body size, chronological age and somatic maturation explained 5–12% of the variance in sedentary behaviors and 20–30% in MVPA. Although complex, physical and physiological changes associated with growth and maturation per se, interacting with psychosocial and other factors in the social environments of youth probably contribute to sex differences in adolescent lifestyles, including physical active and sedentary behaviors.

A role for psychosocial factors on the reduction in physical activity among girls during the transition into puberty and sexual maturation has been postulated (15). Psychosocial factors prominent at this time include decline in self-esteem (more so in early than later maturing girls) and changing interests (including interest in risk taking behaviors associated with alcohol and smoking) and social demands (homework, employment, dating, parental pressures). The decline in physical activity in adolescent females may also be related to physical and physiological changes associated with puberty and the growth spurt. These include changes in body composition (relatively more fatness) and proportions (relative broadening of the hips), discomfort associated with the establishment of regular menstrual cycles and reduction in blood hemoglobin levels (15). Advanced maturation in females is associated with somewhat less proficiency in motor skills, especially weight bearing and endurance tasks (15).

In summary, the contribution of biological maturation to sex differences in physically active and sedentary behaviors has potential implications for the promotion of active lifestyles during adolescence. Needless to say, intervention targeting boys and girls of the same chronological ages may have limitations.

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