American Journal of Epidemiology Advance Access published April 5, 2011

American Journal of Epidemiology

DOI: 10.1093/aje/kwr068

Practice of Epidemiology

Objectively Measured Physical Activity and Sedentary Time in European Adolescents

The HELENA Study

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Initially submitted November 1, 2010; accepted for publication February 18, 2011.

The authors' aim in this cross-sectional study was to characterize levels of objectively measured physical activity and sedentary time in adolescents from 9 European countries. The study comprised 2,200 European adolescents (1,184 girls) participating in the HELENA cross-sectional study (2006–2008). Physical activity was measured by accelerometry and was expressed as average intensity (counts/minute) and amount of time (minutes/day) spent engaging in moderate- to vigorous-intensity physical activity (MVPA). Time spent in sedentary behaviors was also objectively measured. Cardiorespiratory fitness was measured by means of the 20-m shuttle run test. Level of maternal education was reported by the adolescents. A higher proportion of boys (56.8% of boys vs. 27.5% of girls) met the physical activity recommendations of at least 60 minutes/day of MVPA. Adolescents spent most of the registered time in sedentary behaviors (9 hours/day, or 71% of the registered time). Both average intensity and MVPA were higher in adolescents with high cardiorespiratory fitness, and sedentary time was lower in the high-fitness group. There were no physical activity or sedentary time differences between maternal education categories. These data provide an objective measure of physical activity and amount of time spent in sedentary behaviors in a relatively large number of European adolescents.

adolescent; Europe; exercise; motor activity; obesity; physical fitness; sedentary lifestyle; social class

Abbreviations: BMI, body mass index; HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence; MVPA, moderate- to vigorous-intensity physical activity; SD, standard deviation.

There is compelling evidence indicating that physical activity is associated with numerous health benefits in children and adolescents (1–4). Findings from observational studies in youth suggest a dose-response relation between physical activity and health benefits (5). Few studies in Europe have collected comparable information regarding the levels and patterns of objectively measured physical activity in children and adolescents from more than 1 country (6–9), and only 1 study in the United States measured physical activity in a representative sample of adolescents (10).

Physical inactivity is one of the major public health problems of the 21st century (11). Several cross-sectional studies showed that time spent in sedentary activities (measured by accelerometry) is associated with cardiovascular disease risk factors in youth (12–15). The average amount of daily sedentary time in European adolescents is somewhat unknown, since the available information is based on questionnaire data (16) and on a limited number of sedentary behaviors such as television viewing, computer games, Internet use, and studying (17). Assessment of these behaviors provides only a partial picture of overall levels of sedentary behavior in a typical day.

The Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) Study was a multicenter, cross-sectional study performed in 9 European countries that was primarily designed to obtain reliable and comparable data on nutrition and health-related parameters in a relatively large sample of European adolescents (18, 19). Accelerometer data from the HELENA Study provide a great opportunity to determine levels of physical activity and sedentary behavior in current generations of European adolescents.

The purpose of this study was to characterize the levels of objectively measured physical activity and sedentary time among European adolescents participating in the HELENA Study.

MATERIALS AND METHODS

Study participants

The HELENA Study was performed in 10 European cities (hereafter called centers) in 9 countries: Athens (inland city) and Heraklion (Mediterranean island city) in Greece, Dortmund in Germany, Ghent in Belgium, Lille in France, Pécs in Hungary, Rome in Italy, Stockholm in Sweden, Vienna in Austria, and Zaragoza in Spain (18, 19). Data collection took place from 2006 to 2008. Detailed descriptions of the HELENA sampling and recruitment approaches, standardization and harmonization processes, data collection, analysis strategies, quality control activities, and inclusion criteria have been published elsewhere (18, 19).

The current study comprised a total of 2,200 adolescents with valid data on objectively measured physical activity—1,016 boys and 1,184 girls aged 12.5–17.49 years. After receiving complete information about the aims and methods of the study, all adolescents and their parents or guardians gave written informed consent. All participants met the general HELENA Study inclusion criteria: not participating simultaneously in another clinical trial and being free of any acute infection occurring less than 1 week before the study (18, 19). The study protocol was approved by the corresponding local human research review committees of all centers involved (20).

Measures

Physical examination. Weight and height were measured following standard procedures (21), and body mass index (BMI) was calculated as weight (kg) divided by height (m) squared. Adolescents were classified as normal-weight, overweight, or obese according to international BMI cutoff values (22).

Pubertal stage was recorded by a trained researcher of the same gender as the child, according to the method of Tanner and Whitehouse (23), as described elsewhere (24). Pubertal stage data were missing for 70 (6.9%) boys and 92 (7.8%) girls. Since only 9 (0.9%) boys were classified as being in pubertal stage I, these boys were regrouped into pubertal stage II.

Maternal education. Adolescents reported the educational level of their mother. They indicated whether their mother had achieved a primary education, lower secondary education, higher secondary education, or higher education/university degree. This 4-point scale was recoded into a 2-point scale: low education (primary and lower secondary) and high education (higher secondary and higher/university degree) (25). Maternal education data were missing for 54 (5.3%) boys and 45 (3.8%) girls. Previous investigators observed that education may be the most judicious measure of socioeconomic status for use in epidemiologic studies (26). Inquiries on education have the advantage of providing data for all persons, regardless of employment status, that is generally of high reliability and validity and is subject to little change after early adulthood.

Cardiorespiratory fitness. We assessed cardiorespiratory fitness with the 20-m shuttle run test, as described elsewhere (27). We estimated maximal oxygen consumption (mL/kg/minute) using the equation published by Léger et al. (28). This test is valid, reliable, and feasible in young people (29–31). Adolescents were classified into low and high cardiorespiratory fitness levels (i.e., meeting or not meeting the cardiorespiratory fitness standards) based on the FITNESSGRAM Healthy Fitness Zone standards (32, 33). Cardiorespiratory fitness data were missing for 171 (16.8%) boys and 220 (18.6%) girls.

Physical activity and sedentary time. Adolescents were asked to wear an accelerometer (ActiGraph MTI GT1M; ActiGraph LLC, Pensacola, Florida) for 7 consecutive days, starting on the day immediately after they received the monitor during school classes. Adolescents returned the accelerometers to the researchers 8 days later. Participants were instructed to wear the accelerometer on their lower back, attached by an elastic belt, during all waking hours. Since the monitors were not waterproof, participants were asked to take them off while bathing or swimming. The sampling interval (epoch) was set at 15 seconds (34). The data were collected all throughout the academic year.

The data were downloaded into a computer using the manufacturer's software and were later analyzed with an ad hoc Visual Basic data reduction program. The rough data on all participants were analyzed centrally to ensure standardization. We excluded from the analysis bouts of 20 continuous minutes of activity with intensity counts of 0, considering these periods to be nonwearing time (35, 36). Monitor wearing time was calculated by subtracting nonwear time from the total registered time for the day. A recording of more than 20,000 counts/minute was considered a potential malfunction of the accelerometer, and the value was excluded from the analyses. At least 3 days of recording with a minimum of 8 or more hours of registration per day were necessary for the adolescent to be included in the study.

Physical activity levels are shown in 2 ways: 1) average physical activity, expressed as mean counts per minute, and 2) amount of time engaged in moderate- to vigorous-intensity physical activity (MVPA). Average physical activity is a measure of overall physical activity. We calculated mean counts per minute by dividing the sum of total counts per epoch (15 seconds) for a valid day by the number of minutes of wear time in that day across all valid days. We calculated the time engaged in MVPA (defined as $\geq$3 metabolic equivalents) on the basis of a standardized cutoff of $\geq$2,000 counts/minute (37). MVPA was dichotomized into <60 minutes/day and ≥60 minutes/day, according to the current physical activity recommendations (38, 39).

We estimated sedentary time as the amount of time accumulated below 100 counts/minute during periods of wear time (40). Time spent being sedentary was expressed as total duration (hours/day) and as a proportion of wear time (%).

Statistical analysis

All statistical analyses were performed with Predictive Analytics SoftWare, version 18.0 (SPSS, Inc., Chicago, Illinois), and the level of significance was set at $\alpha = 0.05$. Physical activity and sedentary outcome variables were logarithmically transformed to obtain a normal distribution. Gender differences were compared using 1-way analysis of variance, unless otherwise stated. We calculated the estimated mean values for average physical activity and MVPA by age category, pubertal stage, BMI category, cardiorespiratory fitness level, and maternal educational level by means of analysis of covariance, adjusting for center (entered as a random variable) and registered time. We conducted linear regression analyses to examine the associations of average physical activity and MVPA with age, pubertal stage, BMI, cardiorespiratory fitness, and maternal educational level, by inserting each physical activity outcome variable in separate models as the dependent variable; age, pubertal stage, BMI, cardiorespiratory fitness, and maternal education as independent variables (inserted as ordinal variables); and center (entered as a dummy variable) and registered time as confounders. The same analyses were conducted for sedentary time.

We also investigated the physical activity and sedentary behavior differences between Southern European countries and Central-Northern European countries. Greece, Italy, and Spain were grouped into Southern European countries, and Austria, Belgium, France, Germany, Hungary, and Sweden were grouped into Central-Northern European countries. Comparisons between European regions were performed with analysis of covariance, adjusting for registered time. We compared the proportions of adolescents meeting the physical activity recommendations (≥60 minutes/day of MVPA) between Southern and Central-Northern European countries using binary logistic regression analysis, adjusting for registered time. All analyses were performed separately for boys and girls.

RESULTS

The response rates for number of days of wearing the accelerometer and mean registered time are shown in Table 1. Overall, 88% of the adolescents had 4 or more valid days of registration. The mean daily accelerometer wear time within the analyzed sample with 4 or more valid days was 12.9 (standard deviation (SD), 1.5) hours/day. When data were examined by age group and gender, the lowest wear time was 9.7 (SD, 0.9) hours/day for girls aged 16.5–17.49 years, and the highest was 13.8 (SD, 1.6) hours/day for boys aged 12.5–13.49 years.

Boys were more active and less sedentary than girls (Table 2). A higher proportion of adolescent boys met the physical activity recommendations. Adolescents spent most of the registered time in sedentary behaviors (9 hours, or 71% of the registered time). Boys spent less time in sedentary behavior than girls (Table 2). We conducted 1-way analysis of covariance to examine whether the registered time may have confounded the differences between genders, and the results did not change (data not shown).

Average physical activity was lower in older adolescent boys (−2.4% per age group increase; P for trend = 0.006), whereas it did not differ across pubertal stages (Table 3). MVPA was similar across age and pubertal stage groups. Average physical activity and MVPA were lower in adolescent boys with greater BMI (−5.5% and −6.6%, respectively, per BMI category increase; P values for trend were 0.003 and 0.002). In girls, both average physical activity and MVPA were similar across age and pubertal stage groups (Table 3). Both average physical activity and MVPA were similar across BMI categories (−2.6% and 4.2%, respectively, per BMI category increase; P values for trend were 0.143 and 0.055). The results persisted after further controlling for sedentary time (data not shown). Average physical activity and MVPA were higher (from 9% to 15%; all P's < 0.001) in adolescents with a high level of cardiorespiratory fitness (Table 3). No differences were observed between maternal education categories (all P's > 0.2) (Table 2).

Sedentary time was higher in older adolescent boys and girls (2.3% and 1% per age group increase, respectively; both P's for trend < 0.001) and at higher pubertal stages (2.8% and 1% for boys and girls, respectively, per pubertal stage increase; both P's for trend < 0.01) (Table 4). Sedentary time was not associated with BMI in boys, whereas it was lower in adolescent girls with greater BMI (−1.2% per BMI category increase; P for trend = 0.006). Sedentary time was lower in adolescents with high cardiorespiratory fitness (−1.5% for both boys and girls; $P < 0.05$), whereas there were no differences between maternal education categories (both P's > 0.05).

The comparison between Southern and Central-Northern European regions revealed that adolescents from Central-Northern Europe were more active than their peers from Southern Europe (Figure 1); these differences seemed less pronounced in boys than in girls. For boys in Southern Europe, the average intensity and MVPA were both −7% ($P < 0.01$); for girls, they were −18.1% and −23.2%, respectively ($P < 0.001$). The proportions of adolescent boys meeting the physical activity recommendations (≥60 minutes/day of MVPA) were similar between regions (53.7% in Southern Europe vs. 58.6% in Central-Northern Europe; odds ratio = 1.21, 95% confidence interval: 0.96, 1.63), whereas the proportion of adolescent girls meeting the physical activity recommendations was higher in Central-Northern Europe (32.2% in Central-Northern Europe vs. 19.9% in Southern Europe; odds ratio = 1.83, 95% confidence interval: 1.42, 2.51).

Sedentary time also differed between European regions (Figure 2). It was lower in adolescent boys and girls from Central-Northern Europe (2.5% and 2.9%, respectively; $P <$ 0.001). Adolescent boys from Southern Europe and Central-

Table 1. Number of Valid Days and Registered Time of Accelerometer Wear, by Age and Gender, HELENA Study, 2006–2008

Age Group and Gender	No. of Valid Days[a] of Accelerometer Wear									
	3		4		5		6		7	
	%	Mean Time, hours/day[b] (SD)	%	Mean Time, hours/day (SD)	%	Mean Time, hours/day (SD)	%	Mean Time, hours/day (SD)	%	Mean Time, hours/day (SD)
12.5–13.49 years										
Male	8.6	11.8 (1.7)	10.0	12.6 (1.6)	14.8	12.4 (1.9)	22.0	12.9 (1.1)	44.5	13.8 (1.6)
Female	8.1	11.9 (1.7)	6.8	12.7 (2.0)	14.4	12.6 (1.3)	19.8	13.2 (1.6)	50.9	13.6 (1.2)
13.5–14.49 years										
Male	11.2	11.7 (1.8)	10.2	11.9 (1.1)	14.3	13.0 (1.1)	20.9	12.8 (1.3)	43.3	13.5 (1.2)
Female	7.5	11.5 (1.5)	10.3	12.0 (1.3)	20.2	12.4 (1.3)	19.4	12.6 (1.1)	42.6	13.2 (1.3)
14.5–15.49 years										
Male	11.6	11.6 (1.8)	12.3	12.1 (1.4)	8.6	12.5 (1.4)	21.0	13.1 (1.5)	46.5	13.6 (1.7)
Female	9.4	11.8 (1.7)	11.3	11.6 (1.3)	15.8	12.5 (1.4)	22.0	12.6 (1.1)	41.6	13.0 (1.6)
15.5–16.49 years										
Male	11.2	11.8 (1.6)	13.9	12.2 (1.4)	14.5	12.4 (1.3)	21.0	12.7 (1.2)	39.4	13.3 (1.2)
Female	6.9	12.1 (1.6)	14.4	12.0 (1.1)	14.4	11.9 (1.1)	21.6	12.5 (1.0)	42.8	13.1 (1.4)
16.5–17.49 years										
Male	11.8	11.8 (1.5)	11.8	11.4 (1.2)	11.8	12.0 (1.3)	16.5	12.9 (1.1)	48.2	13.6 (1.6)
Female	3.4	9.7 (0.9)	4.5	13.2 (0.6)	19.3	12.6 (1.4)	25.0	12.8 (1.0)	47.7	13.4 (1.3)

Abbreviations: HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence; SD, standard deviation.
[a] A valid day was defined as 8 or more hours of accelerometer wear.
[b] Mean amount of registered time of accelerometer wear.

Northern Europe spent 69.8% and 68.4% of their registered time in sedentary behaviors, respectively ($P = 0.002$), whereas adolescents girls spent 72.9% and 71.0% of their registered time, respectively ($P < 0.001$). These findings persisted after further adjustment for age, pubertal stage, and BMI (data not shown).

DISCUSSION

The main purpose of this study was to characterize physical activity levels and sedentary time in current generations of European adolescents using the same method (accelerometry) in all 9 countries. Over half of the adolescent boys and nearly one-third of the girls met the physical activity recommendations (≥60 minutes/day of MVPA). These European adolescents spent on average 70% of their waking time (approximately 9 hours/day) in sedentary behaviors, that is, in activities that expend little energy. In agreement with the findings of other studies using objective methods, boys were more active than girls, and physical activity was lower in older adolescents (especially boys) and those with greater BMI. We observed that the group of adolescents with a high level of cardiorespiratory fitness was also more physically active than the low-fitness group. Younger adolescents and those with high cardiorespiratory fitness spent less time in sedentary behaviors. Sedentary behavior times were similar across weight status categories in boys, whereas sedentary time was slightly lower in girls with greater BMI. There was no association of physical activity or sedentary time with maternal education. To our knowledge, this is the first comparable objective quantification of physical activity and overall sedentary time in a relatively large sample of adolescents from 9 European countries.

The proportion of adolescents observed to meet the physical activity recommendations in the present study is of concern and contrasts with the results obtained in the late 1990s in the European Youth Heart Study (1998–1999). Ortega et al. (41) reported that approximately 70% of Swedish adolescent boys and 60% of adolescent girls aged 15 years met the physical activity recommendations (age-specific cutoff used to calculate the time spent in MVPA (42): approximately 1,706 counts/minute). Data from Denmark, Portugal (Madeira), Estonia, and Norway showed that 82% of adolescent boys and 62% of adolescent girls met the public health recommendations (cutoff for calculating time spent in MVPA: 1,500 counts/minute) (6). Figures from the 2003–2004 National Health and Nutrition Examination Survey are more alarming. Troiano et al. (10) reported that only 11% and 4% of US adolescent boys and girls (ages 12–19 years), respectively, spend at least 60 minutes in MVPA on a daily basis (age-specific cutoffs used to calculate time spent in MVPA (42): approximately 2,020–3,239 counts/minute). Corresponding figures from younger groups indicated that, on average, 42% of US children aged 6–11 years meet the public health recommendations (10). In southern English children aged 11 years, Riddoch et al. (7) reported that only 5.1% of boys and 0.4% of girls aged 11 years met the physical activity recommendations, although the Avon Longitudinal Study

Table 2. Characteristics of the Study Sample (European Adolescents Aged 12.5–17.49 Years), HELENA Study, 2006–2008

	Total (n = 2,200)			Boys (n = 1,016)			Girls (n = 1,184)			P Value[a]
	No.	%	Median (IQR[b])	No.	%	Median (IQR)	No.	%	Median (IQR)	
Age, years			14.9 (13.9–15.8)			14.9 (13.8–15.8)			14.9 (13.9–15.8)	0.780
Pubertal stage[c]										<0.001
I		1			1			0		
II		6			8			4		
III		22			23			21		
IV		39			37			41		
V		32			31			34		
Height, cm			166 (159–172)			171 (167–177)			162 (158–167)	<0.001
Weight, kg			57.2 (50.7–65.0)			60.8 (52.4–69.2)			55 (49.4–61.6)	<0.001
Body mass index[d]			20.6 (18.8–22.9)			20.4 (18.6–22.9)			20.7 (18.9–22.9)	0.359
No. of activity days measured			6 (5–7)			6 (5–7)			6 (5–7)	0.115
Registered time, minutes/day			769 (713–821)			778 (716–826)			762 (709–815)	0.002
Overall activity, counts/minute			410 (325–519)			464 (367–581)			370 (300–451)	<0.001
MVPA, minutes/day			55 (41–71)			64 (48–81)			49 (37–62)	<0.001
Sedentary activity, hours/day			9.0 (8.2–9.8)			9.0 (8.0–9.8)			9.1 (8.4–9.8)	<0.001
Registered time at sedentary level, %			71 (67–75)			70.0 (65–74)			72 (69–76)	<0.001
Meeting recommended activity level[e]	903	41.0		577	56.8		326	27.5		<0.001

Abbreviations: HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence; IQR, interquartile range; MVPA, moderate- to vigorous-intensity physical activity.

[a] P for gender difference.

[b] 25th–75th percentiles.

[c] Stage of sexual maturation, recorded according to the method of Tanner and Whitehouse (23).

[d] Weight (kg)/height (m)^2.

[e] Recommended activity level: ≥60 minutes of MVPA daily.

of Parents and Children used a relatively higher cutoff to calculate the time spent in MVPA (i.e., 3,600 counts/minute), which will have greatly influenced the results. Direct comparisons among studies cannot be done because of methodological differences such as epoch length, cutoff points used to classify MVPA, and participants' ages. There is a need for standardization of methods to make the data among studies fully comparable.

The results of the present study are consistent with the findings of previous reports showing that boys are more active than girls (6, 7, 10, 41–43). Further, we confirm that older adolescent boys are less active than younger peers. Also in line with previous research (1), we observed an inverse association between physical activity and BMI, so that the normal-weight group was also the most active one.

Cardiorespiratory fitness is an important health marker in children and adolescents (44, 45), and despite its strong genetic component (46), observational and intervention studies have shown that regular physical activity is one of the main determinants of fitness in adolescents (1, 44). Our results confirm previous findings and indicate that the most active children are also those with high cardiorespiratory fitness. The association between physical activity and socioeconomic status in adolescents is contradictory, mainly because of inconsistent use of measures for both variables (47). We observed no association between physical activity and socioeconomic status (assessed by maternal education), which concurs with other studies using objective physical activity data in adolescents (48). Results from studies of younger persons give support to the present findings (7, 49).

Sedentary behaviors refer to those activities that do not increase resting energy expenditure substantially—that is, no more than 1.5 times' resting energy expenditure (50). These activities involved sitting, reclining, and lying down, such as watching television, playing video or computer games, Internet surfing, studying, reading, playing a musical instrument, etc. In the present study, we observed that European adolescents spend on average 9 hours/day of their waking time (66%–71% and 70%–73% of the registered time in boys and girls, respectively) in sedentary activities. These figures are slightly higher than those observed in US adolescents (National Health and Nutrition Examination Survey, 2003–2004) (40). Matthews et al. (40) reported that US adolescents aged 12–19 years spend nearly 60%

Table 3. Physical Activity Levels in European Adolescents, by Age Group, Pubertal Stage, Body Mass Index Category, Cardiorespiratory Fitness, and Maternal Education, HELENA Study, 2006–2008[a]

	Boys (n = 1,016)						Girls (n = 1,184)					
	No.	%	Average Activity, counts/minute		MVPA, minutes/day		No.	%	Average Activity, counts/minute		MVPA, minutes/day	
			Mean	95% CI	Mean	95% CI			Mean	95% CI	Mean	95% CI
Age group, years												
12.5–13.49	209	20.6	504	478, 531	68	64, 72	222	18.8	396	378, 413	51	48, 53
13.5–14.49	235	23.1	501	477, 526	68	64, 71	324	27.4	379	364, 393	49	47, 51
14.5–15.49	267	26.3	481	460, 502	66	63, 69	310	26.2	384	369, 398	51	49, 53
15.5–16.49	220	21.7	466	439, 493	65	61, 69	240	20.3	390	374, 407	53	50, 55
16.5–17.49	85	8.4	456	411, 501	61	54, 67	88	7.4	364	321, 408	50	44, 57
P for trend			0.006		0.059				0.704		0.057	
Pubertal stage[b]												
II	88	9.3	509	468, 551	69	63, 75	42	3.8	390	328, 452	50	41, 60
III	221	23.4	506	482, 530	69	65, 72	235	21.5	381	362, 400	49	46, 52
IV	347	36.7	485	467, 502	66	64, 69	448	41.0	403	389, 416	54	52, 56
V	290	30.7	502	473, 531	69	65, 74	367	33.6	379	363, 395	50	48, 53
P for trend			0.155		0.440				0.301		0.806	
Body mass index[d] category												
Normal-weight	870	79.0	494	481, 507	67	65, 69	722	75.5	385	376, 393	51	49, 52
Overweight	186	16.9	472	446, 498	64	60, 68	175	18.3	381	363, 399	49	47, 52
Obese	45	4.1	444	396, 492	60	53, 68	59	6.2	350	311, 388	44	38, 50
P for trend			0.003		0.002				0.143		0.055	
Cardiorespiratory fitness												
Low	267	31.6	450	428, 473	62	58, 65	345	35.8	375	360, 390	49	47, 51
High	578	68.4	520	502, 537	71	68, 73	619	64.2	398	387, 410	52	50, 54
P value			<0.001		<0.001				<0.001		<0.001	
Maternal education												
Low	305	31.7	499	475, 523	69	65, 72	391	34.3	378	364, 391	50	48, 52
High	657	68.3	481	467, 495	65	63, 67	748	65.7	385	376, 395	50	49, 52
P value			0.394		0.195				0.591		0.881	

Abbreviations: CI, confidence interval; HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence; MVPA, moderate- to vigorous-intensity physical activity.

[a] Estimates and *P* values were adjusted for country (entered as a dummy variable) and registered time.

[b] Stage of sexual maturation, recorded according to the method of Tanner and Whitehouse (23).

[c] Weight (kg)/height (m)^2.

(approximately 8 hours/day) of their waking time in sedentary activities. They also showed that overall sedentary time was higher in older adolescents, which is in agreement with our results. The analysis with pubertal stages confirms the observed age-related increase.

We observed no association between sedentary time and BMI in boys, whereas a slight decrease was observed across BMI categories in girls (−1.2% per BMI category). Other cross-sectional studies found no association between objectively measured sedentary time and BMI or other indicators of adiposity in children and adolescents (14, 51, 52). Our data extend these findings, which suggests that at least MVPA is more strongly associated with lower adiposity, irrespective of time spent in sedentary activities (8, 14, 51–53).

Time spent being sedentary was 1.5% lower in adolescents with a high cardiorespiratory fitness level, which concurs with the results obtained in children and adolescents participating in the European Youth Heart Study (partial $r = -0.11$, $P < 0.0001$) (15). Studies using self-reported data (i.e., television viewing or computer use) also showed an inverse association between sedentary time and cardiorespiratory fitness (54, 55).

The association between objectively measured sedentary time and socioeconomic status is not conclusive. A study conducted with preschool Scottish children using accelerometers found no evidence of differences in sedentary time across socioeconomic status groups (based on a composite of social class, car ownership, unemployment, and overcrowded housing) (49). In light of the unequivocal association of sedentary behaviors with adverse health outcomes (12–14, 17, 56–59) and mortality risk (60–63), and given the amount of time spent being sedentary, public health testing

Table 4. Time Spent in Sedentary Activities and Percentage of Registered Time Spent at the Sedentary Level in European Adolescents, by Age Group, Pubertal Stage, Body Mass Index Category, Cardiorespiratory Fitness, and Maternal Education, HELENA Study, 2006–2008[a]

	Boys (n = 1,016)					Girls (n = 1,184)				
	No.	%	Mean Time, hours/day	95% CI	% of Registered Time Sedentary	No.	%	Mean Time, hours/day	95% CI	% of Registered Time Sedentary
Age group, years										
12.5–13.49	209	20.6	8.6	8.4, 8.7	66.1	222	18.8	8.9	8.8, 9.0	70.3
13.5–14.49	235	23.1	8.7	8.6, 8.8	67.8	324	27.4	9.1	9.0, 9.2	71.7
14.5–15.49	267	26.3	9.1	8.9, 9.2	70.1	310	26.2	9.2	9.1, 9.3	72.4
15.5–16.49	220	21.7	9.2	9.0, 9.3	70.8	240	20.3	9.2	9.1, 9.3	71.9
16.5–17.49	85	8.4	9.2	9.0, 9.4	70.9	88	7.4	9.4	9.2, 9.6	72.6
P for trend			<0.001					<0.001		
Pubertal stage[b]										
II	88	9.3	8.5	8.2, 8.7	65.1	42	3.8	9.0	8.6, 9.3	69.4
III	221	23.4	8.7	8.6, 8.9	67.0	235	21.5	9.1	9.0, 9.2	72.1
IV	347	36.7	9.1	9.0, 9.2	69.8	448	41.0	9.1	9.1, 9.2	71.3
V	290	30.7	9.1	9.0, 9.3	71.5	367	33.6	9.2	9.1, 9.3	72.6
P for trend			<0.001					0.005		
Body mass index[c] category										
Normal-weight	870	79.0	8.9	8.8, 9.0	69.3	722	75.5	9.2	9.1, 9.2	72.0
Overweight	186	16.9	8.8	8.7, 9.0	68.5	175	18.3	9.0	8.9, 9.1	70.9
Obese	45	4.1	8.8	8.5, 9.0	68.1	59	6.2	9.0	8.8, 9.2	71.2
P for trend			0.308					0.006		
Cardiorespiratory fitness										
Low	267	31.6	9.0	8.9, 9.1	69.2	345	35.8	9.2	9.1, 9.3	72.4
High	578	68.4	8.8	8.7, 8.9	69.0	619	64.2	9.1	9.0, 9.1	71.5
P value			0.047					0.002		
Maternal education										
Low	305	31.7	8.8	8.7, 8.9	68.1	391	34.3	9.0	9.0, 9.1	71.2
High	657	68.3	8.9	8.9, 9.0	69.8	748	65.7	9.1	9.1, 9.2	72.2
P value			0.146					0.064		

Abbreviations: CI, confidence interval; HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence.
[a] Estimates and *P* values were adjusted for country (entered as dummy variable) and registered time.
[b] Stage of sexual maturation, recorded according to the method of Tanner and Whitehouse (23).
[c] Weight (kg)/height (m)^2.

and recommendations aimed at decreasing overall sedentary behaviors are needed.

We also compared regional differences (Southern Europe vs. Central-Northern Europe) in objectively measured physical activity and sedentary time. Overall, adolescents from Central-Northern Europe were more active (approximately 7% of registered time was spent in MVPA in boys and approximately 20% in girls) than their peers from Southern Europe. The prevalences of adolescent boys meeting the physical activity recommendations were similar between regions (53.7% in Southern Europe and 58.6% in Central-Northern Europe, respectively), whereas differences became evident in girls: One in every 3 girls from Central-Northern Europe met the physical activity recommendations, whereas only 1 of every 5 girls from Southern Europe met the recommendations. The figures parallel the results regarding sedentary time, which was approximately 2.7% lower (i.e., 12–15 minutes/day) in Central-Northern Europe than in Southern Europe. These findings may help to explain the differences in obesity and related metabolic disorders between European countries (64–66).

Several limitations must be acknowledged. There is no definitive consensus regarding the best cutoff point with which to assess MVPA and sedentary activities using the ActiGraph accelerometer. In the present study, we used the standardized cutoff of ≥2,000 counts/minute for MVPA (37), which is equivalent to walking on a treadmill or on ground at 4 km/hour (67, 68). For sedentary activities, we used the cutoff of <100 counts/minute, which has been validated in adolescent girls (69) and has been widely used in previous studies (40, 70). Further, it seems that among the commercially available accelerometers, the one used in the

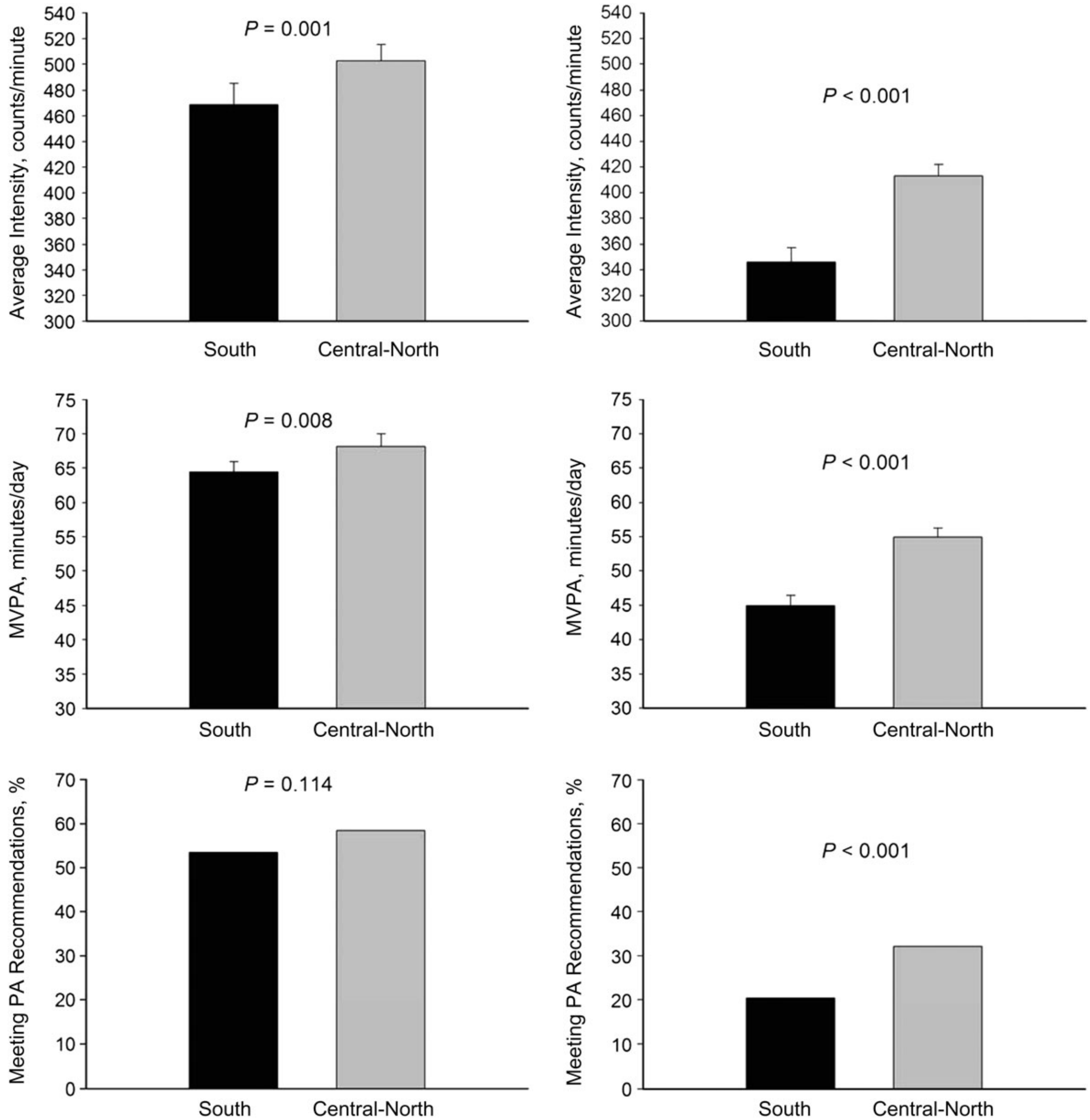

Figure 1. Amount and intensity of physical activity (PA) among adolescents in Southern European countries (Greece, Italy, and Spain) and Central-Northern European countries (Austria, Belgium, France, Germany, Hungary, and Sweden), HELENA Study, 2006–2008. Left and right columns correspond to boys (South, $n = 378$; Central-North, $n = 638$) and girls (South, $n = 447$; Central-North, $n = 737$), respectively. Values are mean estimates adjusted for registered time of accelerometer wear. The recommended PA level is $\geq$60 minutes of moderate- to vigorous-intensity physical activity (MVPA) daily. *P* values are for regional comparisons. Bars, 95% confidence interval. (HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence.)

present study (ActiGraph MTI, model GT1M) showed the best correlation with doubly labeled water-derived energy expenditure (71) and small intermonitor variability (72). It would have been ideal to collect the data after a few days of wearing the activity monitors to avoid reactivity (adolescents may modify their habitual activity or sedentary behavior when they know they are being measured); however, this was not possible for logistic reasons. In addition, the accelerometer underestimates activities that involve minimal vertical displacement, such as cycling, and it does not capture load-bearing activities well. Moreover, the activity monitor must be removed during swimming, which may further result in underestimation of physical activity level in some adolescents. The HELENA Study was not designed to analyze the data by city/country, which hampers deeper comparisons between them. Finally, the cross-sectional design of our study does not allow for establishing any causal relations.

One of the advantages of the HELENA Study, however, was the strict standardization of the fieldwork, which precludes to a great extent the kind of immeasurable confounding bias that often interferes when comparing results from isolated studies (18, 19). Notable also is that the

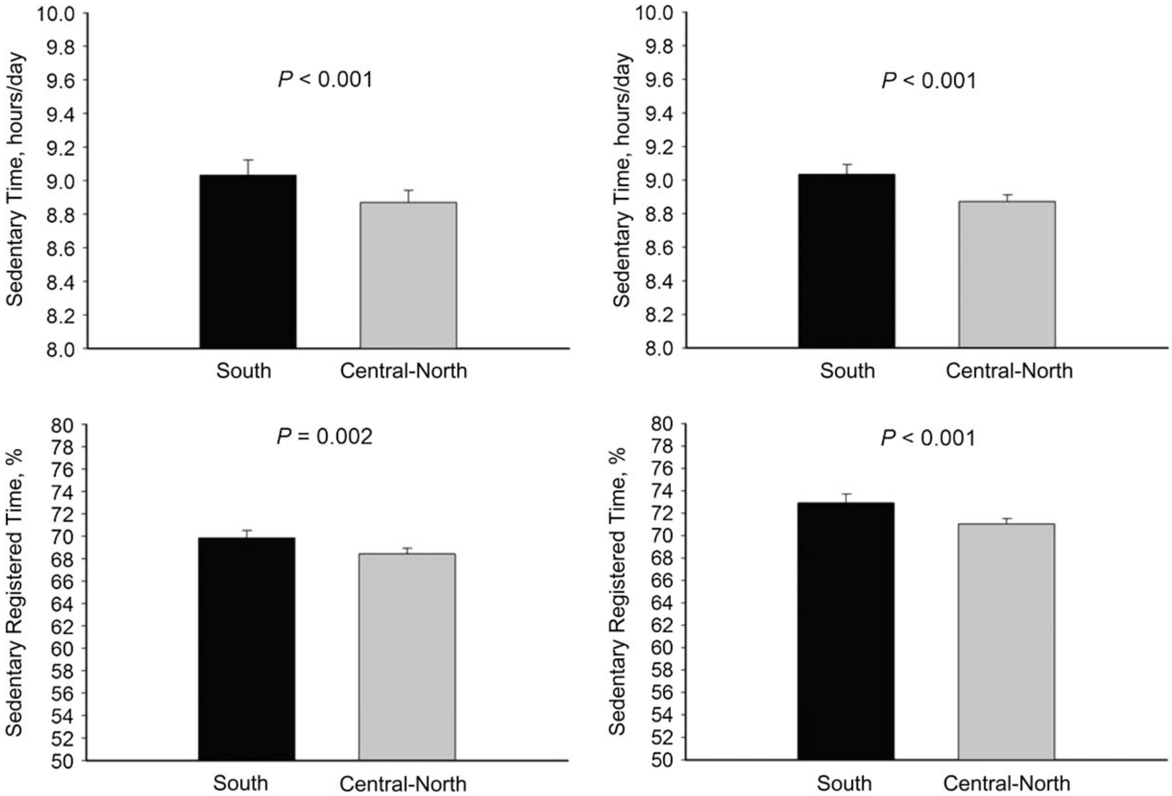

Figure 2. Amount of sedentary time and percentage of registered time spent at the sedentary level among adolescents in Southern European countries (Greece, Italy, and Spain) and Central-Northern European countries (Austria, Belgium, France, Germany, Hungary, and Sweden), HELENA Study, 2006–2008. Left and right columns correspond to boys (South, $n = 378$; Central-North, $n = 638$) and girls (South, $n = 447$; Central-North, $n = 737$), respectively. Values are mean estimates adjusted for registered time of accelerometer wear. P values are for regional comparisons. Bars, 95% confidence interval. (HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence.)

recording of data was set at 15-second intervals, in concordance with consensus recommendations for youth (34). An additional strength of the present study is that most of the adolescents were compliant with the measurement procedures. The minimum number of days required to be included in the analysis was 3, but overall, 88% of adolescents had 4 or more days. Furthermore, while a minimum of 8 hours of registration per day was set as an inclusion criterion, the mean daily accelerometer wear time was 12.9 (SD, 1.5) hours.

In summary, these data provide an objective measure of physical activity and amount of time spent in sedentary activities in a relatively large number of European adolescents. The HELENA estimates can be used for several purposes: 1) for international comparisons, 2) as baseline reference levels for monitoring, and 3) to assess the effectiveness of intervention strategies promoting physical activity in European countries.

ACKNOWLEDGMENTS

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This study took place with the financial support of the European Community Sixth Framework Programme (Research, Technological Development and Demonstration) (contract FOOD-CT-2005-007034), the Swedish Council for Working Life and Social Research, the Swedish Heart-Lung Foundation (grant 20090635), the Spanish Ministry of Education (grant EX-2008-0641), the Spanish Ministry of Health: Maternal, Child Health and Development Network (grant RG08/0072), and the Spanish Ministry of Science and Innovation (grant RYC-2010-05957).

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Conflict of interest: none declared.

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