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# Health Inequalities in Urban Adolescents: Role of Physical Activity, Diet, and Genetics



**WHAT'S KNOWN ON THIS SUBJECT:** Individuals living in Mediterranean countries have historically had a lower risk of cardiovascular disease. Important changes in diet and lifestyle have taken place in these countries in recent years, and it is unknown how these changes might influence current cardiovascular health.



**WHAT THIS STUDY ADDS:** Fitness and fatness levels indicate that urban adolescents from southern Europe are less healthy than those from central northern Europe. The extent to which these differences might be explained by physical activity, diet, and genetics is analyzed and discussed in this article.

## abstract



**OBJECTIVE:** Coordinated European projects relying on standardized methods are needed to identify health inequalities across Europe. This study aimed to compare fitness, fatness, and cardiometabolic risk between urban adolescents from the south and center-north of Europe and to explore whether physical activity (PA) and other factors might explain these differences.

**METHODS:** The Healthy Lifestyle in Europe by Nutrition in Adolescence cross-sectional project comprised 3528 adolescents from the south (4 cities) and central-north (6 cities) of Europe, 1089 of whom provided blood samples for analysis. Fitness (strength, speed-agility, and cardiorespiratory fitness), total and abdominal fatness (anthropometry and bioelectrical impedance), and cardiometabolic risk (z scores including fitness, fatness, blood lipids, insulin resistance, and blood pressure) were assessed. The analyses were adjusted for socioeconomic factors, objectively measured PA (accelerometry), total energy intake and diet quality, and genetic variants of the *FTO* rs9939609 polymorphism.

**RESULTS:** Adolescents from southern Europe were less fit and fatter according to all markers ( $P < .001$ ). Differences in cardiometabolic risk scores were not consistent. Adolescents from the south were less active and this would largely explain the differences observed in speed-agility and cardiorespiratory fitness. Differences in total and abdominal fatness could not be explained by PA, energy intake, diet quality, or *FTO* rs9939609 polymorphism.

**CONCLUSIONS:** Fitness and fatness levels indicate that urban adolescents from the south are less healthy than those from central-northern Europe. Our data suggest that differences in PA might explain differences in important health-related fitness components, yet factors explaining the differences in fatness encountered remain unknown. *Pediatrics* 2014;133:e884–e895

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(Continued on last page)

Mediterranean countries such as Spain, Italy, and Greece share economic, environmental, cultural, and social factors that make them likely to differ in health status from other countries located in central and northern Europe. For example, data from the European Association for the Study of Obesity ([www.easo.org](http://www.easo.org)) indicate that the prevalence of childhood overweight/obesity is higher in southern European countries than in the center and the north. Although this information is valuable, the data are based on studies conducted at different times and using different methods, so accurate comparisons between geographic areas are difficult.<sup>1</sup> In addition, information concerning adiposity levels (fat mass) is called for to provide useful complementary information to the BMI data currently available.

Another key health marker in childhood and adolescence is physical fitness.<sup>2,3</sup> The main health-related physical fitness (hereafter fitness) components are cardiorespiratory fitness, muscular strength, and speed-agility. Similarly, some authors have extensively reviewed the existing data on this subject collected in different areas in the world.<sup>4</sup> As noted earlier, however, comparisons between studies conducted at different times by using different methods should be treated with caution. Consequently, whether there are any real differences in fitness between youth across different European geographic areas is currently unknown but may turn out to have important implications for public health.

Likewise, we have not found any studies exploring differences in traditional cardiometabolic risk factors, such as triglycerides, high-density lipoprotein (HDL) cholesterol, glucose, insulin, and blood pressure, either in children or adolescents from different parts of Europe.

To understand health inequalities in Europe more fully, there is a need for

studies collecting data at the same time in different areas of the continent, by using standardized protocols of assessment. Within the context of the EU-funded Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) project, our study included adolescents from 10 European cities (9 countries) and provided an excellent opportunity to investigate differences in health markers between south and center-north of Europe. Our main aim in this study was to explore whether fitness, fatness, and cardiometabolic risk factors differ between urban adolescents from southern and central-northern Europe. Because previous findings in other studies conducted under the aegis of the HELENA project showed that objectively measured physical activity (PA) levels were lower in urban adolescents from the south compared with those from the center-north of Europe,<sup>5</sup> a second aim of the current study was to investigate the extent to which PA levels might explain geographic differences in fitness, fatness, and cardiometabolic risk factors in urban European adolescents. Finally, we also explored the role of other potential factors such as energy intake, diet quality, and variants of the *FTO* gene in the differences observed.

## METHODS

### Study Design and Sample

Details of the methods and sampling techniques used in the HELENA cross-sectional project have been published elsewhere.<sup>6-8</sup> A total of 3528 adolescents aged from 12.5 to 17.5 years participated in the study,<sup>9</sup> one-third of whom (1089) were randomly selected for blood analysis.<sup>9</sup> The sampling size was calculated with a confidence level of 95% and  $\pm 0.3$  error in the worst of situations for the parameter BMI (for complete description about sample size calculation, see the HELENA methodologic study<sup>7</sup>). Data collection took

place between 2006 and 2008. To make maximum use of the data, all participants with valid data on the main study outcomes were included. Consequently, sample sizes vary among models, as indicated in Tables 1 and 2.

Having received complete information about the aims and methods of the study, all the parents/guardians signed a consent form, and all the adolescents gave their assent to participate in the study. The study was undertaken following the ethical guidelines of the Declaration of Helsinki 1961 (revised Edinburgh 2000) and the current legislation concerning clinical research in humans in each of the participating countries. The protocol was approved by human research review committees at the centers involved.<sup>10</sup>

### Definition of the South and Center-North of Europe

Four of the 10 cities participating in the HELENA project were part of 3 Mediterranean countries: Athens and Heraklion (both island cities) in Greece, Rome in Italy, and Zaragoza in Spain. These 4 cities were classified as belonging to the south of Europe and were compared with the other 6 cities, which belong to higher latitudes, namely, the center-north of Europe: Dortmund in Germany, Ghent in Belgium, Lille in France, Pécs in Hungary, Stockholm in Sweden, and Vienna in Austria (Fig 1).

As reported in the methodologic study of the HELENA project,<sup>7</sup> we sampled European cities of  $>100\,000$  inhabitants. The geographic distribution was not random and not represented by strata but it was decided according to the following criteria: representation of territorial units (countries) of Europe according to geographic location (north, south, east, west), cultural reference and socioeconomic situation, and selection of a territorial unit (city) in the country, which is representative of the average level of

**TABLE 1** Characteristics of the Whole Study Sample and Stratification by Geographic Location in Europe

	All			South of Europe			Center-North of Europe			<i>P</i> <sup>a</sup>
	<i>n</i>	Mean	SEM	<i>n</i>	Mean	SEM	<i>n</i>	Mean	SEM	
Age, y	3528	14.7	0.0	1291	14.5	0.0	2237	14.8	0.0	<.001
Height, cm	3528	165.8	0.2	1291	163.7	0.2	2237	167.0	0.2	<.001
Wt, kg	3528	59.1	0.2	1291	59.2	0.3	2237	59.1	0.3	.743
	<i>n</i>	Freq.	%	<i>n</i>	Freq.	%	<i>n</i>	Freq.	%	
Gender:	3528	1845	52.3	1291	690	53.4	2237	1155	51.6	.31
female										
Tanner stages	3116			978			2138			<.001
I		12	0.4		5	0.5		7	0.3	
II		178	5.7		64	6.5		114	5.3	
III		698	22.4		224	22.9		474	22.2	
IV		1312	42.1		301	30.8		1011	47.3	
V		916	29.4		384	39.3		532	24.9	
FAS	3475			1257			2218			<.001
Low		461	13.3		239	19.0		222	10.0	
Medium		1974	56.8		822	65.4		1152	51.9	
High		1040	29.9		196	15.6		844	38.1	
Maternal education	3315			1224			2091			.01
Primary		281	8.5		125	10.2		156	7.5	
Secondary		1917	57.8		708	57.8		1209	57.8	
University		1117	33.7		391	31.9		726	34.7	

<sup>a</sup> Differences in the characteristics of the study sample between the south and center-north of Europe were analyzed by analysis of variance for continuous variables and by  $\chi^2$  tests for categorical variables.

demography, cultural, social, and economic markers. The cities were equivalent and comparable between countries. Gender ratio, mean age, and BMI were similar between nonparticipating and participating adolescents within each study center and in the overall sample.<sup>11</sup>

This sample should not, however, be considered representative of rural areas, whole countries, or whole European regions.

### Physical Fitness

Detailed information on fitness protocols, operational manual, training workshops, and standardized instructions to participants, together with the fitness characteristics of the sample, have been published elsewhere.<sup>12,15</sup> In brief, cardiorespiratory fitness was assessed by the 20-meter shuttle-run test,<sup>14</sup> and maximum oxygen consumption ( $V_{O_{2max}}$ , mL/kg/min) was estimated by using the equation reported by Léger et al.<sup>14</sup> Muscular fitness was assessed by means of the

handgrip strength<sup>15–17</sup> and standing long-jump<sup>16,18</sup> tests. Speed-agility was assessed with the 4×10-meter shuttle-run test.<sup>19</sup> These physical fitness tests have proved in other studies to be valid and reliable in young people.<sup>12,20–22</sup>

### Physical Examination, Anthropometrics, and Body Composition

The anthropometric methods followed in general in the HELENA project have been described elsewhere.<sup>23</sup> In brief, we measured height, weight, waist circumference, and 6 skinfolds (triceps, biceps, subscapular, suprailiac, thigh, and calf) using standard protocols. BMI was calculated as body weight (kilograms) divided by squared height (meters) and classified into weight status categories.<sup>24,25</sup> Body-fat percentage was calculated by the equation described by Slaughter et al.<sup>26</sup> and fat mass expressed in kilograms was calculated. In addition, a tetra-polar bioelectrical impedance

device (BIA 101 Akern, Italy) was used, and fat mass (kilograms) was calculated as described elsewhere.<sup>23,27</sup> Pubertal status was assessed during a medical examination by a physician/pediatrician according to the methods described by Tanner and Whitehouse.<sup>28</sup>

### Other Cardiometabolic Risk Factors

A detailed description of blood-sampling procedures has been published elsewhere.<sup>9</sup> In brief, serum concentrations of cardiovascular risk factors were measured from fasting blood samples in centralized laboratories. Serum total cholesterol, HDL cholesterol, triglycerides, glucose, and insulin were measured using standard protocols. The homeostasis model assessment index was calculated.<sup>29</sup>

Systolic and diastolic blood pressure was measured with an automatic oscillometric device (Omron M6, The Netherlands). The adolescents sat on a chair quietly for 5 minutes before the measurements were made on the extended right arm. Two measurements were taken 5 minutes apart, the lowest value being recorded in mm Hg. Mean arterial pressure was calculated.<sup>30</sup>

We computed 2 well-established cardiometabolic risk scores (gender- and age-specific z scores) to be used in the main analyses, as proposed by Andersen et al.<sup>31</sup> and Martínez-Vizcaino et al.<sup>32,33</sup> See the biomarkers included in each score in the legend to Table 2. For sensitivity analyses, we selected these 2 risk scores, which largely differ from each other in the risk factors included (eg, markers of total versus abdominal fatness, homeostasis model assessment index versus fasting insulin, etc, for the Andersen's versus Martínez-Vizcaino scores, respectively).

### Socioeconomic Status

The Family Affluence Scale (FAS) describes family expenditure and

**TABLE 2** Differences in Fitness, Fatness, and Cardiometabolic Risk Scores in Urban Adolescents From the South and Center-North of Europe

	South of Europe			Center-North of Europe			<i>P</i> <sup>a</sup>
	<i>n</i>	Mean	SEM	<i>n</i>	Mean	SEM	
<b>Fitness</b>							
Upper-body muscular strength: hand grip, kg	1144	30.1	0.2	1964	31.0	0.1	<.001
Lower-body muscular strength: Standing long jump, cm	1139	154.4	0.8	1949	169.0	0.6	<.001
Speed/agility: 4×10-m shuttle run, s <sup>b</sup>	1038	12.4	0.0	1942	12.1	0.0	<.001
Cardiorespiratory fitness: VO <sub>2max</sub> (mL/kg/min)	948	40.0	0.2	1713	41.3	0.2	<.001
<b>Fatness</b>							
Total adiposity: BMI	1223	22.1	0.1	2090	21.0	0.1	<.001
Total adiposity: at mass, kg: skinfolds	1129	16.4	0.3	2015	13.4	0.2	<.001
Total adiposity: at mass, kg: bioelectrical impedance	1216	14.0	0.2	2031	11.6	0.2	<.001
Abdominal adiposity: waist circumference, cm	1208	73.8	0.2	2045	71.3	0.2	<.001
<b>Cardiometabolic risk scores</b>							
Score 1, Andersen et al <sup>31c</sup>	280	0.11	0.04	472	-0.03	0.03	.007
Score 2, Martinez-Vizcaino et al <sup>32,33c</sup>	379	0.08	0.03	596	-0.05	0.03	.003
<b>Lifestyle</b>							
Moderate-to-vigorous PA, min/d	792	52.8	0.8	1307	61.5	0.6	<.001
Vigorous PA, min/d	792	16.4	0.5	1307	20.3	0.3	<.001
Average PA, counts/min	792	396.0	5.2	1307	457.4	4.0	<.001
Sedentary time, min/d	792	556.3	3.0	1307	534.2	2.3	<.001
Energy intake, Kcal/d	746	2108.0	27.6	1466	2220.7	19.2	<.001
Diet quality index <sup>d</sup>	746	61.1	0.6	1796	49.1	0.4	<.001

VO<sub>2max</sub>, estimated from the 20-m shuttle run test by using the Leger's equation.<sup>14</sup>

<sup>a</sup> ANCOVA models were adjusted for age, gender, height, and socioeconomic factors (FAS and maternal education). BMI was not adjusted for height because it is already part of the index (ie, weight divided by squared height).

<sup>b</sup> In this test the lower the score (in seconds) the higher the performance.

<sup>c</sup> The cardiometabolic risk score 1 is an average value computed from the gender- and age-specific z scores of sum of 4 skinfolds, HOMA index, systolic blood pressure, triglyceride, total cholesterol/HDL ratio, and cardiorespiratory fitness (VO<sub>2max</sub>; this score was inverted multiplying by -1)<sup>31</sup>; the score 2 is an average value computed from the gender- and age-specific z scores of waist circumference, fasting insulin, triglyceride/HDL cholesterol ratio, and mean arterial pressure.<sup>32,33</sup>

<sup>d</sup> In this variable, the higher the index the higher the quality.

consumption based on 4 items: own bedroom, number of cars in the family, number of PCs in the home, and Internet access.<sup>34</sup> The FAS is an indicator of affluence.<sup>35,36</sup> Maternal education was self-reported by the mothers and used as an additional indicator of socioeconomic status.<sup>37–39</sup>

### Objectively Measured PA

A detailed description of the assessment of PA in the HELENA project has been published elsewhere.<sup>5,40</sup> Briefly, adolescents were asked to wear an accelerometer (GT1M, Actigraph, Pensacola, FL) for 7 consecutive days during waking hours except when engaged in water-based activities. The time sampling interval (epoch) was set at 15 seconds. Moderate-to-vigorous PA

(MVPA) and vigorous PA were defined by the cutoff points of  $\geq 2000$  counts/minute and  $\geq 4000$  counts/minute, respectively.<sup>5,31,40–42</sup> Sedentary time was defined using the standard cutoff point of  $\leq 100$  counts/minute.<sup>5,43–45</sup> Average PA was computed as the total number of counts divided by total wearing time in minutes and expressed as counts/minutes. At least 3 days of recording with a minimum of  $\geq 8$  hours of registration per day were necessary for the adolescent to be included in the study.<sup>5</sup>

### Nutritional Assessment

Every participant was asked to fill in a 24-hour dietary recall by using the HELENA-DIAT software on 2 non-consecutive days within a period of 2 weeks.<sup>46</sup> In the analyses, we used

a surrogate of the amount (ie, total energy intake) and a surrogate of quality of the diet, the Diet Quality Index for Adolescents (DQI-A).<sup>47,48</sup> The DQI-A consists of 3 principles forming the basis of a healthy diet: dietary equilibrium, dietary diversity, and dietary quality.<sup>48,49</sup> A final DQI-A score was calculated, with a higher score indicating a better-quality diet. The validity of the HELENA-DIAT and the DQI-A has been confirmed elsewhere.<sup>49,50</sup>

### Genetic Factors

For the purpose of the current study, we chose 1 of the genes most closely associated with adiposity levels, the obesity-associated gene (*FTO*) and particularly the *FTO* rs9939609 polymorphism.<sup>51</sup> *FTO* rs9939609 genotyping was done centrally (at the Institut Pasteur de Lille, France) by using an Illumina system (Illumina, Inc, San Diego, CA), Golden-Gate technology (GoldenGate Software, Inc, San Francisco, CA).<sup>52,53</sup> The genotyping success rate was 100%. Overall, 2% of the sample was double-genotyped and the concordance rate was 99.9%.<sup>54</sup> The genotype distribution respected the Hardy-Weinberg equilibrium ( $P = .56$ ).

### Statistical Analysis

Binary logistic regression was used to analyze the likelihood of being overweight/obese versus normal weight (underweight excluded) according to geographical location (the south compared with the center-north of Europe). Differences in fitness, fatness and cardiometabolic risk scores between adolescents were analyzed by analysis of covariance (ANCOVA). All the models were adjusted for a set of potential confounders: age, gender, height (except when BMI was the outcome), and socioeconomic factors (FAS and mother's educational level).

To test whether differences in MVPA between adolescents from the south





**FIGURE 1**  
The southern and central-northern European cities sampled in the HELENA study.

and center-north of Europe might explain differences in health outcomes, we tested the differences using ANCOVA with and without additional adjustment for MVPA. To make different variables visually comparable and on the same scale, they were all transformed into gender- and age-specific z scores:  $(\text{value} - \text{mean}) / \text{SD}$ . In exploratory analyses, we additionally adjusted for other potential confounders as indicated in the Results section. Overall, there were no significant interactions according to gender, and thus the data from the main analyses were presented for boys and girls together. All statistical analyses were made by using the SPSS software (version 20.0.0, IBM SPSS Statistics, IBM Corporation), the  $\alpha$  error being set at 5%.

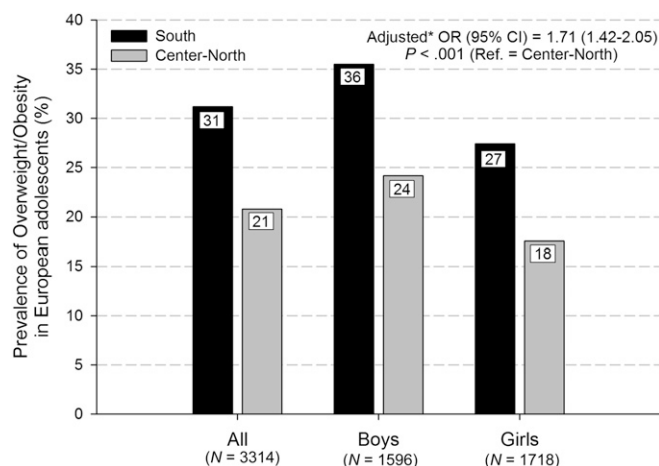
## RESULTS

Characteristics of the study sample are shown in Table 1. Adolescents from the

south performed worse than those from the center-north of Europe in all the fitness tests studied ( $P < .001$ ), and they also had higher levels of total and abdominal fatness (Table 2). Both cardiometabolic risk scores were higher in adolescents from the south than in those from the center-north ( $P < .001$ ; Table 2), yet mixed findings were observed when risk factors were analyzed separately (see Supplemental Table 3). Compared with adolescents from the center-north of Europe, adolescents from the south of Europe had healthier values in total cholesterol, triglycerides, and triglycerides/HDL ratio, yet unhealthier values in HDL cholesterol and diastolic blood pressure, with no differences in the rest of variables studied. Adolescents from the south were less active and more sedentary than those from the center-north of Europe ( $P < .001$ ; Table 2), as previously reported.<sup>5</sup> Adolescents from the south showed a lower energy in-

take and better-quality diet than their peers from the center-north of Europe ( $P < .001$ ; Table 2), as previously reported.<sup>55</sup> All the analyses were adjusted for age, gender, height, and socioeconomic factors: FAS and maternal educational level. Adjustment for pubertal status instead of age did not modify the results (data not shown). Figure 2 shows that the prevalence of overweight/obesity was markedly higher in adolescents of both genders from southern compared with central-northern Europe (31% vs 21%).

The role of MVPA in the differences found in fitness, fatness, and cardiometabolic risk scores is shown in Figs 3, 4, and 5, respectively. Differences in muscular strength could not be explained by MVPA, although the differences observed in speed-agility were moderately attenuated after adjustment for MVPA ( $P$  reduced from  $< .001$  to  $.02$ ), and the differences in



**FIGURE 2**

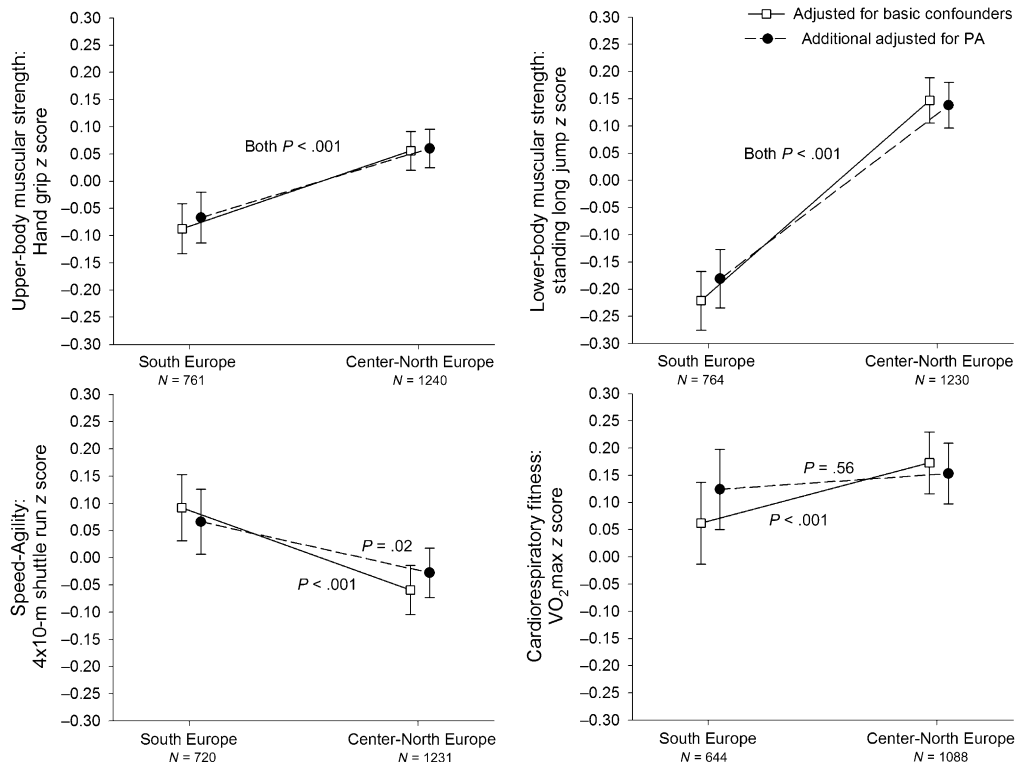
Prevalence of overweight/obesity in urban adolescents from the south and center-north of Europe. \*The OR shown is for the whole sample and the model was adjusted for age, gender, height, and socioeconomic factors (FAS and maternal education). The dependent variable was coded as 1 = overweight/obesity, 0 = normal weight, with underweight participants being excluded from the analysis. Note that the figure visually shows the lack of interaction, the differences being equal in boys and girls (ie, roughly a 10-point difference). Gender interactions were formally tested, and significant interactions were not found for any of the main outcomes; consequently, the rest of the results are presented for boys and girls together. CI, confidence interval; OR, odds ratio.

cardiorespiratory fitness disappeared after adjustment for MVPA ( $P$  reduced from  $< .001$  to  $.56$ ). The differences in

cardiorespiratory fitness were also attenuated after adjustment for sedentary time, although they remained

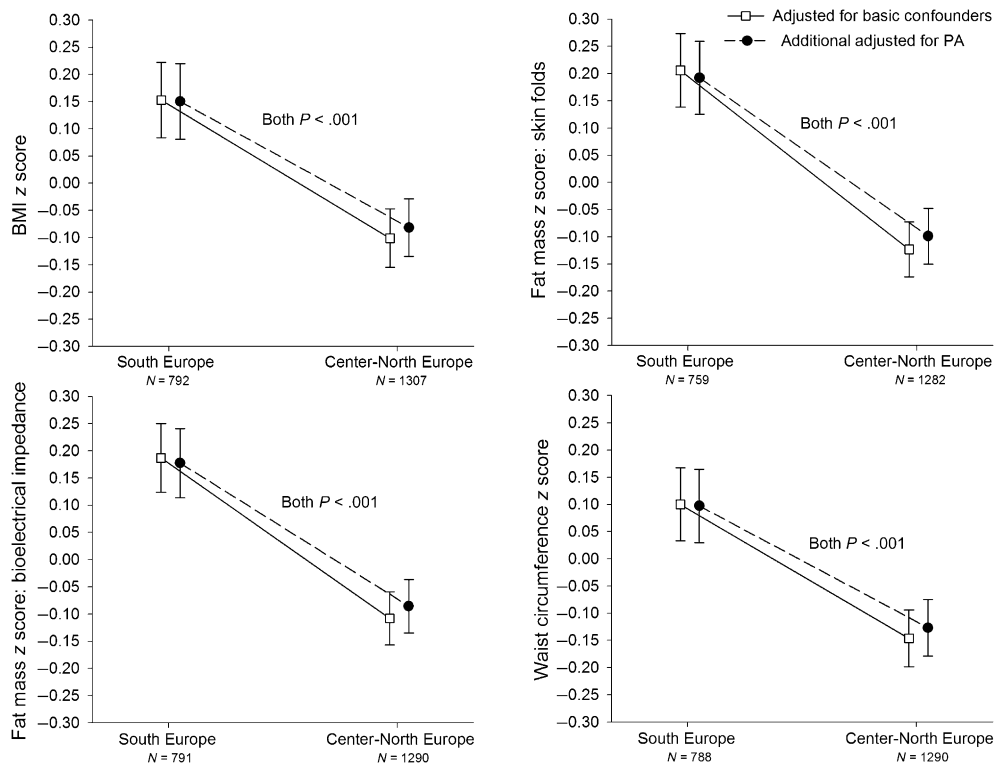
significant ( $P$  reduced from  $< .001$  to  $.01$ ; data not shown). Differences in speed-agility were moderately attenuated after further adjustment for total fatness (fat mass,  $P$  reduced from  $< .001$  to  $.1$ ), and differences in cardiorespiratory fitness disappeared after additional adjustment for total fatness (either BMI or fat mass,  $P$  reduced from  $< .001$  to  $> .5$ ).

MVPA, in contrast, had little or no influence on the differences in either total or abdominal fatness (Fig 4). Likewise, adjustment for sedentary time, average PA, or vigorous PA instead of MVPA did not alter the results (data not shown). The differences in the cardiometabolic risk scores (Table 2) were no longer significant when the analyses were restricted to the sample with PA data (Fig 5). Compliance rates for accelerometers in the whole sample were similar between adolescents from the south and those from the center-north



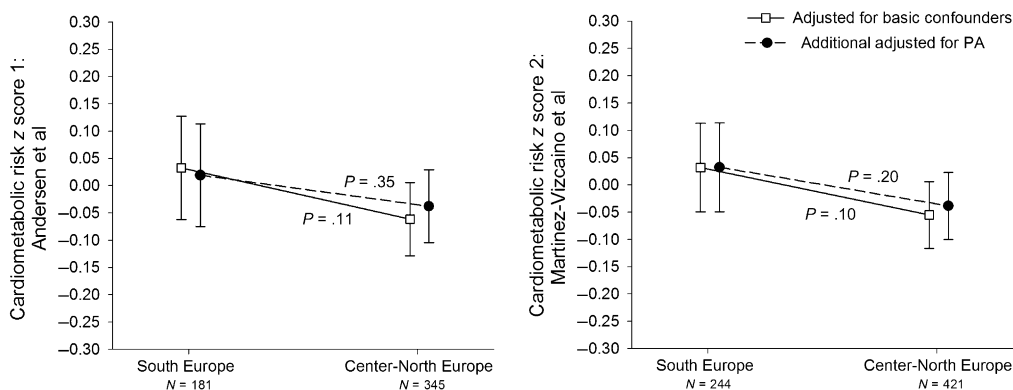
**FIGURE 3**

Differences in health-related fitness components between urban adolescents from the south and the center-north of Europe with and without additional adjustment for MVPA.  $VO_{2max}$ , estimated from the 20-meter shuttle run test using Leger's equations. All ANCOVA models were adjusted for age, gender, height, and socioeconomic factors (FAS and maternal education).



**FIGURE 4**

Differences in total (BMI and body-fat percentage) and abdominal fatness (waist circumference) between urban adolescents from the south and center-north of Europe with and without additional adjustment for MVPA. All ANCOVA models were adjusted for age, gender, height (except for BMI), and socioeconomic factors (FAS and maternal education).



**FIGURE 5**

Differences in cardiometabolic risk scores between urban adolescents from the south and center-north of Europe with and without additional adjustment for MVPA. All ANCOVA models were adjusted for age, gender, height, and socioeconomic factors (FAS and maternal education). The cardiometabolic risk score 1 is an average value computed from the gender- and age-specific z scores of the sum of 4 skinfolds, homeostasis model assessment index, systolic blood pressure, triglyceride, total cholesterol/HDL ratio, and cardiorespiratory fitness ( $VO_{2max}$ ; this score was inverted by multiplying by  $-1$ )<sup>31</sup>; the score 2 is an average value computed from the gender- and age-specific z scores of waist circumference, fasting insulin, triglyceride/HDL cholesterol ratio, and mean arterial pressure.<sup>32,33</sup>

of Europe (63.9% and 61.5%, respectively; 2.4% difference). However, when the analysis was restricted to the subsample with valid data in all the risk factors included in the risk scores, compliance rates were lower in

adolescents from the south of Europe than in those from the center-north of Europe (64.4% and 72.4%, respectively, 8% difference). In addition, significant differences were observed in both risk scores between adolescents with

accelerometer data (they had healthier values) and those without accelerometer data in adolescents from the south ( $P < .01$ ), but not in adolescents from the center-north of Europe ( $P > .2$ ). These associations were not modified to



any marked extent for any of the confounders considered.

In exploratory analyses, we examined whether other factors (ie, fitness, dietetic, or genetic factors) might explain the differences encountered in the adiposity markers, which remained significant even after further adjustment for all these variables (data not shown). No significant difference ( $P > .2$ ) was observed in the distribution of the *FTO* rs9939609 polymorphism genotype between adolescents from the south (15.6%, 49.0%, and 35.5%, for AA, TA, and TT genotypes, respectively) and the center-north (17.7%, 43.9%, and 38.4%, respectively). Finally, we built a fully adjusted model including the set of basic confounders, *FTO* rs9939609 polymorphism and 2 major lifestyle factors, PA (either variable) and diet (both total energy intake and diet quality included simultaneously), and the adolescents from the south of Europe still proved to be more fat according to all the markers studied (data not shown).

## DISCUSSION

This study contributes to our knowledge of health inequalities across Europe, including 4 particularly important findings. First, urban adolescents from the south of Europe are less fit in terms of muscular strength, speed-agility, and cardiorespiratory fitness and are more fat, both in total and abdominal fatness, than their counterparts from the center-north. Second, mixed and inconsistent findings were observed in cardiometabolic risk scores and factors. Third, PA largely explained the differences observed in speed-agility and cardiorespiratory fitness, and these differences could also be explained by fatness, suggesting that urban adolescents in the south did not perform so well in cardiorespiratory fitness and speed-agility tests due in part to their lower PA and higher adiposity levels. Fourth, the differences

observed in adiposity between urban adolescents from southern and central-northern Europe persisted even after accounting for the set of basic confounders (age, gender, height, and socioeconomic factors) plus PA, energy intake and diet quality, and the *FTO* polymorphism. It is important to bear in mind that this study describes the differences observed in the HELENA adolescents living in the 10 European cities mentioned, and the data are not therefore representative of rural areas, whole countries, or whole European regions.

## Fitness

The fact that the differences observed in speed-agility and particularly cardiorespiratory fitness, a major health marker, could be explained by differences in PA supports the importance of PA as a stimulus of fitness in the population, yet the cross-sectional nature of the data does not allow stating cause–effect links. We have not found other similar multicenter European Union projects in adolescents comparing fitness across regions of Europe, which rules out comparisons with previous studies. Nevertheless, some meta-studies have reviewed and compared published data, and their conclusions concur with ours. The fitness level of Spanish adolescents was compared with that of adolescents from other countries and revealed the former were less fit than adolescents from most of the other countries studied.<sup>56</sup> Also in line with our results, Olds et al reported that children and adolescents from Portugal, Italy, and Greece showed worse fitness levels than those from other parts of the world for which fitness data are available.<sup>4</sup>

## Fatness

Currently available information on adiposity in adolescents from different

parts of Europe is limited to BMI and the prevalence of overweight/obesity. Our study contributes to this knowledge by comparing total body fat and waist circumference in addition to BMI. Our results strongly and consistently support the conclusion that adolescents from the south have higher levels of total and abdominal fatness compared with adolescents from the center-north of Europe and that these results could not be explained by MVPA, sedentary time, or fitness. Because it has been reported elsewhere that vigorous rather than moderate PA is associated with total and abdominal fatness,<sup>57–59</sup> we also adjusted our models for vigorous PA, but the differences in fatness between the south and center-north persisted, as they did after additional adjustment for dietetic (total energy intake and diet quality) or/and genetic variants linked to fatness (*FTO* rs9939609 polymorphism).

## Cardiometabolic Risk

The 2 risk scores studied, after adjusting for relevant confounders, revealed that urban adolescents from southern Europe had a worse cardiometabolic profile than their peers from the center-north. Nevertheless, once we focused on the sample of participants with accelerometer data, these differences were no longer significant. This might be due to the lower accelerometer compliance observed in urban adolescents from the south compared with those from the center-north of Europe. It has been consistently shown in epidemiologic studies that participants with higher compliance in accelerometer data have higher socioeconomic status,<sup>60–62</sup> which in turn is associated with healthier outcomes.<sup>37–39</sup> In addition, once the analyses were conducted on single risk factors composed in the 2 risk

scores presented, mixed findings were found, without a clearly superior profile in adolescents from either the south or center-north of Europe. This makes us to conclude that no consistent differences were observed in cardiometabolic factors. We have not found other studies comparing these risk factors in a standardized fashion between adolescents from different regions of Europe, so comparisons with previous data are not possible.

### Public Health Implications

It is important to put the current findings into a public health perspective. A vital question for European health policies is to what extent the differences in fitness and fatness identified in this study might lead to poorer health in the future and higher needs for health care, which will inevitably impinge on the economic budget. The World Health Organization—Europe statistics (<http://data.euro.who.int/hfad>) for the countries included in our study provide figures contrary to ours, for example, age-standardized cardiovascular disease mortality (age 0–64) per 100 000 persons in 2009 was 32.9 in Spain, Italy, and Greece compared with 45.3 in France, Germany, Austria, Hungary, and Sweden, with no data available for Belgium. Similarly, age-standardized cancer mortality was 62.8 in the south compared with 78.2 in the center-north of Europe. Finally, 2009 life expectancy in the south was 2 years longer than in the center-north of Europe, including Belgium (81.3 compared with 79.3). The worse health status in adolescents from southern Europe observed in this study might somehow be compensated by other factors later in life, thus inverting their current health

status. Alternatively, the differences observed in adolescents today might have repercussions later in life, leading to healthier adults, a higher risk of mortality, and shorter life expectancy in southern Europe in the near future.

### Limitations and Strengths of the Study

In addition to the nonrepresentativeness of rural areas and whole countries already mentioned, there are a number of limitations that should be considered. We accounted for a complete set of potential confounders (age, height, socioeconomic factors, objectively measured PA, dietetic and genetic variants), but we did not study other dietetic, genetic, epigenetic, and environmental factors, the possible role of which remain to be determined. In addition, we observed differences between both groups of adolescents in some of the factors studied (eg, socioeconomic variables, height, PA). Even if these variables were entered as covariates in the models, it has been suggested that their potential confounding effect cannot be fully (mathematically) controlled for when using ANCOVA.<sup>65</sup>

The main strength of the study is the thorough standardization of the methods and collection of data throughout all the cities involved, allowing us to make accurate comparisons. In addition, the study includes a broad set of health indicators, including the main health-related fitness components assessed using valid and reliable tests,<sup>3,20–22</sup> measurements of total and abdominal fatness using different methods such as anthropometry (using accurate and valid fat equations in adolescents<sup>64</sup>), bioelectrical impedance (measured in >3200 participants), and a significant number of cardiometabolic risk

factors (centrally analyzed blood samples). The inclusion of these health indicators in a single study, the standardization of the measurements, and the time frame imposed for data collection make it one of the most comprehensive examinations of health inequalities in adolescence across Europe. The objective measurement of PA by accelerometry, the inclusion of diet quality and genetic variants, and the specific analysis of their role in the health indicator differences observed are additional strengths of this study.

### CONCLUSIONS

Our data clearly indicate that urban adolescents from southern Europe are markedly less physically fit than their counterparts from the center-north. The lower level of speed-agility and cardiorespiratory fitness observed in urban adolescents from the south seems to be largely explained by their lower engagement in PA. This finding illustrates indirectly the importance of PA for the health of young people at a population level, yet because of the cross-sectional nature of the data, cause–effect relationships cannot be established. Our results also suggest that urban adolescents from the south have higher levels of adiposity than their peers from the center-north of Europe, with these differences persisting after accounting for age, gender, socioeconomic factors, lifestyle factors (PA and diet), and obesity-related genetic variants (*FTO* gene). Further study is needed to identify the reasons urban adolescents from the south are more fat than their peers from central-northern Europe. Finally, this study does not provide evidence of consistent differences in other cardiometabolic risk factors between

adolescents from the south and their peers from the center-north of Europe, but it is plausible that the differences observed in fitness and fatness in adolescence might influence cardiometabolic risk factors in the long-term.

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(Continued from first page)

#### KEY WORDS

physical fitness, fatness, obesity, body-fat distribution, cardiovascular disease risk factors, adolescence

#### ABBREVIATIONS

ANCOVA—analysis of covariance

DQI-A—Diet Quality Index for Adolescents

FAS—Family Affluence Scale

HDL—high-density lipoprotein

HELENA—Healthy Lifestyle in Europe by Nutrition in Adolescence

MVPA—moderate-to-vigorous physical activity

PA—physical activity

Vo<sub>2max</sub>—maximum oxygen consumption

Dr Ortega conceptualized and designed the part of the study concerning fitness assessment, coordinated the collection of fitness data, carried out the statistical analyses, and drafted the initial manuscript; Dr Ruiz conceptualized and designed the part of the study concerning fitness assessment, substantially contributed to the analysis and interpretation of the data, and critically reviewed the manuscript; Drs Labayen, Martínez-Gómez, and Cuenca-García substantially contributed to the analysis and interpretation of the data and critically reviewed the manuscript; Dr Vicente-Rodríguez designed the data collection instruments, coordinated and supervised data collection, and critically reviewed the manuscript; Dr Gracia-Marco actively participated in the data collection and critically reviewed the manuscript; Drs Manios, Beghin, Polito, Widhalm, Marcos, González-Gross, Kafatos, Breidenassel, Moreno, Sjöström, and Castillo conceptualized and designed the study, designed the data collection instruments, and coordinated and supervised data collection; Dr Molnar conceptualized and designed the study, designed the data collection instruments, and coordinated and supervised data collection; and all authors approved the final manuscript as submitted.

The authors of this paper take sole responsibility for its content. See Supplemental Information for a complete list of the HELENA project members.

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## Health Inequalities in Urban Adolescents: Role of Physical Activity, Diet, and Genetics

Francisco B. Ortega, Jonatan R. Ruiz, Idoia Labayen, David Martínez-Gómez, Germán Vicente-Rodríguez, Magdalena Cuenca-García, Luis Gracia-Marco, Yannis Manios, Laurent Beghin, Dénes Molnar, Angela Polito, Kurt Widhalm, Ascensión Marcos, Marcela González-Gross, Anthony Kafatos, Christina Breidenassel, Luis A. Moreno, Michael Sjöström and Manuel J. Castillo  
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