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Original article

Socioeconomically Disadvantaged Groups and Metabolic Syndrome in European Adolescents: The HELENA Study

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A B S T R A C T

Purpose: Psychosocial stressors derived from socioeconomic disadvantages in adolescents can result in higher risk of metabolic syndrome (MetS). We aimed to examine whether socioeconomic disadvantages were associated with MetS independent of lifestyle and whether there was a dose-response relationship between the number of cumulated socioeconomic disadvantages and risk of MetS.

IMPLICATIONS AND CONTRIBUTION

Maternal education was the most important determinant of adolescent metabolic syndrome risk

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Methods: This study included 1,037 European adolescents (aged 12.5−17.5 years). Sociodemographic variables and lifestyle were assessed by self-reported questionnaires. Disadvantaged groups included adolescents with low-educated parents, low family affluence, migrant origin, unemployed parents, and nontraditional families. MetS risk score was calculated as the sum of sex- and age-specific z-scores of waist circumference, blood pressure, lipids, and insulin resistance. Linear mixed-effects models adjusted for sex, age, pubertal status, and lifestyle were used to study the association between social disadvantages and MetS risk score.

Results: Adolescents with low-educated mothers showed a higher MetS score (.54 [.09−.98]; β estimate and 99% confidence interval) compared to those with high-educated mothers. Adolescents who accumulated more than three disadvantages (.69 [.08−1.31]) or with missing information on disadvantages (.72 [.04−1.40]) had a higher MetS risk score compared to nonsocioeconomically disadvantaged groups. Stronger associations between socioeconomic disadvantages and MetS were found in male than in female adolescents.

Conclusions: Adolescents with low-educated mothers or with more than three socioeconomic disadvantages had a higher MetS risk, independent of lifestyle, potentially due to higher psychosocial stress exposure. Policy makers should focus on improving low-educated familiesa and more disadvantaged families' knowledge on nutrition and physical activity to help them cope better with stress.

and the association was independent of lifestyle. Other socioeconomic disadvantages seemed not to be associated with a higher risk, though a dose-response relationship existed between the number of social disadvantages and metabolic syndrome risk. Low-educated families should be targeted to tackle health disparities.

The metabolic syndrome (MetS), defined as a cluster of metabolic abnormalities including abdominal obesity, hypertension, insulin resistance (IR), elevated triglyceride (TG), and reduced high-density lipoprotein cholesterol (HDL-C) circulating concentrations, is a major public health problem [1]. Having one of the components of MetS increases the risk of developing MetS in the future and can lead to a high lifetime burden of cardiovascular disease risk. Early detection of MetS components could enable targeted interventions to reduce the health and economic burden of cardiovascular diseases [2]. In 2018, the prevalence of MetS worldwide was estimated at 25% [3] in adults and 10% in adolescents, with an increasing trend in the last decades [4]. This estimation differs widely by sex, age, race, ethnicity, region, and the definition of the MetS used [5].

Socioeconomic status (SES) is an important determinant of MetS. Previous studies on SES and MetS [6] have reported an inverse association, particularly in women [7]. Even during childhood, a low SES seems to predict a higher risk of MetS in adulthood independently of conventional childhood risk factors and the person's SES in adulthood [8]. In addition to classical SES indicators (including educational level, occupation, and income), there are other vulnerable groups (referred to hereafter as socioeconomically disadvantaged groups) that have not been extensively investigated but have been recently linked with higher MetS risk (or some of its components) independent of SES. These include adolescents whose parents are migrants, adolescents from nontraditional families, and adolescents with unemployed parents [9−11].

Socioeconomically disadvantaged groups often have adverse health behaviours that increase the risk of MetS such as the consumption of energy-dense foods, a highly sedentary lifestyle, lower physical activity (PA) levels, smoking, and heavy drinking [12]. These disadvantaged groups are more exposed to obesogenic environments [13] and they face more psychosocial stress derived from these social vulnerabilities. Psychologically stressful family environments and lack of access to social capital, including social support, might explain the association between childhood disadvantages and adult health [14]. In particular, social disadvantages can create a state of chronic stress that increases the activity of the hypothalamic-pituitary-adrenal axis leading to hypercortisolism and contributing to the development of several features of MetS [15].

We aimed to investigate the association between socioeconomic disadvantages and MetS risk score independent of lifestyle in a large cohort of European adolescents. Our hypothesis was that the effect of socioeconomic factors on MetS risk is independent of lifestyle, since there are other factors (e.g. stress derived from these socioeconomic disadvantages) that may explain this association. During adolescence, stress and many negative lifestyle behaviours intensify [16]. Moreover, we wanted to test which socioeconomic disadvantages (low-educated parents, low family affluence, migrant origin, unemployed parents, living in a nontraditional family) are the strongest MetS predictors.

Methods

Population

The current investigation used data from the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study (HELENA-CSS). The HELENA study is a cross-sectional multicenter study conducted between 2006 and 2007 in 10 European cities of more than 100,000 inhabitant each, located in separated geographical points in Europe (Athens and Heraklion, Dortmund, Ghent, Lille, Pecs, Rome, Stockholm, Vienna, and Zaragoza). The cities were selected by convenience based on the location of the partners in the HELENA study consortium. As a requirement, each city had a population with a high diversity in cultural background and socioeconomic situations; and the presence of an active research group assuring sufficient expertise and resources to successfully perform studies in adolescents [17]. The total sample included 3,528 adolescents, aged 12.5−17.5 years, from which one third were randomly included in the subsample that was selected for blood collection resulting in a total of 1,089 adolescents (Supplemental Table S1 compares the sample used in the study with the sample that had missing values for the MetS risk score). Adolescents were excluded from the database if they met one or more of the following exclusion criteria: age <12.5 or ≥17.5 years; no measurement of weight and/or height; completion of <75% of the tests; participation in another clinical trial; or contracting an acute infection during the week prior to the examination.

Adolescents and parents or legal guardians gave written informed consent for examinations and data collection for themselves and their children, respectively. Ethical approval was obtained from the research ethics authority of each participating center.

Sociodemographic indicators and disadvantages scoring

To define and capture socioeconomically disadvantaged groups [18,19] within the sample, the following information was collected using a questionnaire completed by the adolescent participants.

Mother’s and father’s education was categorized as low education or medium/high education (higher secondary and higher education/university degree) [18,19].

Family affluence was based on the number of cars and computers owned by the household, the presence/absence of an Internet connection and whether adolescents had their own bedroom. A score of 0–3 was coded as a low family affluence and 4–8 as a medium or high [19].

Family structure: adolescents from “traditional families” lived with both biological parents while those from nontraditional families were defined as those not living with their biological parents [18].

Origin of parents: a migrant background was assumed if one or both parents were born in a country different from the one where the study took place [18,19].

Employment status: children with unemployed parents were those whose mother or father was unemployed, or those living on social assistance or welfare [18,19].

We calculated a total socioeconomic disadvantage score by summing the number of indicators of socioeconomic disadvantages a child was exposed to (low maternal education, low paternal education, low family affluence, nontraditional family, migrant, unemployed) [20,21]. This score ranged from 0 to six and was divided into four categories (3–6 disadvantages, 2, 1, and no disadvantages).

Biochemical/clinical indicators and MetS scoring

After biospecimen collection and examinations at the children's school, the following indicators were measured and assessed:

Waist circumference was used as an indicator of central adiposity, and it was measured in triplicate at the midpoint between the lowest rib and the iliac crest, using an anthropometric tape (SECA 200) [22].

Systolic blood pressure (SBP) and diastolic blood pressure (DBP)– were measured with an automatic oscillometric device (OMRON M6). Two measurements were taken with a 5-minute interval. The lowest value of the two recordings of systolic and diastolic measurement was selected.

Blood samples were taken by a nurse or medical doctor after 10 hours of fasting. For this study, glucose and HOMA-IR were selected as glucose indicators, whereas HDL and TG were taken as indicators of lipids. A more detailed description of the blood analysis has been previously reported elsewhere [23].

Pubertal stage was determined using Tanner's five-stage scale [24] during a clinical examination of each adolescent at their school. This information along with adolescent's age and sex were covariates in this study.

For each of the MetS risk components, sex- and age-specific z-scores were calculated. Following the definition of Ahrens et al. [25], a MetS score was calculated as the sum of sex- and age-specific z-scores of waist circumference, HOMA-IR index, mean of z-scores of SBP and DBP, and mean of z-score of HDL-C multiplied by -1 and z-score of TG. A higher score indicates poorer metabolic health.

Lifestyle indicators

Information on each adolescent's lifestyle factors was collected using self-report questionnaires.

PA was assessed using the question “Are you physically active for at least 1 hour each day?” Responses were categorized as: “Yes, for more than 6 months”, “Yes, for 6 months or less,” or “No”.

Diet Quality Index for Adolescents

Dietary intake was assessed by two, nonconsecutive 24 h recalls. A Diet Quality Index for Adolescents (DQI-A) score was calculated by considering dietary quality, diversity, and equilibrium. Dietary quality expressed whether the adolescent made the optimal food quality choices within a food group. Dietary diversity described the degree of variation in the diet. Dietary equilibrium was calculated as the difference between an adequacy score (percentage of food groups with intake above the minimum recommended intake) and the excess component (percentage of food groups exceeding the upper level of the recommended intake).

DQI-A was calculated as the mean of dietary quality, diversity, and equilibrium and could range from −33% to 100%, with higher values reflecting a higher diet quality.

More detailed information about the DQI-A can be found elsewhere [26]. Using the median value of our sample, we categorized adolescents as showing a low DQI-A (≤median) or high DQI-A (>median, with median = 54.66).

Smoking status was assessed by: “Have you ever smoked tobacco?” and “if yes, how often do you smoke tobacco at present?”. Those who reported “yes” were coded as “smokers”. Participants that reported having smoked in the past but not currently were recoded as “ever smoker”. Participants who never smoked tobacco were coded as “nonsmokers”.

Alcohol intake: Adolescents reported consumption of alcoholic beverages in two 24h recalls and were labelled as those who consumed alcohol in any of the two recalls and those who did not.

Statistical analyses

For descriptive analyses, chi-square tests were used to examine differences in the study population by adolescent's MetS risk (at risk vs. not at risk). Linear mixed-effects models were applied to study the associations between the six disadvantaged groups and MetS risk score including a random school and a random country effect to account for the clustered study design. Linear mixed-effects models were also used to assess the association between socioeconomic disadvantages and each of the MetS risk components, separately. Basic models were adjusted for age, sex, and Tanner stage. Fully adjusted models were additionally adjusted for lifestyle factors (PA, DQI, smoking, and alcohol intake) to assess the effect of social disadvantages not being mediated through lifestyle factors. Social vulnerabilities were also adjusted for parental education and family affluence to assess whether the effect was independent of classical SES indicators. For all our models, the nonvulnerable group was taken as a reference value.

As respondents with missing socioeconomic and lifestyle information may not be a random subset of the population-based survey, excluding these records from analyses may bias study results [27]. To avoid this issue, missing information/values in socioeconomic variables, vulnerability indicators, and lifestyle factors were coded as a separate category.

After excluding adolescents with missing values for MetS risk score and any of the components of MetS, this analysis included 1,037 adolescents (Supplemental Figure S1). The main characteristics of the subjects in both samples did not differ substantially based on comparison of the study sample with the sample that had missing values for the MetS risk score (Supplemental Table S1).

In order to test the robustness of our results several sensitivity analyses were conducted for the available sample size: (1) including a categorical outcome of MetS with different definitions of the MetS risk; (2) estimating all models stratified by sex; and (3) using family affluence as a continuous variable. Particularly for the first analysis, a dichotomous MetS variable was defined as having at least one of these conditions: abdominal obesity, hypertension, HOMA-IR, elevated TG, and reduced HDL-C (instead of three given the low number of adolescents diagnosed with MetS in our sample) according to the World Health Organization cutoffs [28]. Further analyses included the following definitions: AHA pediatric (American Heart Association), International Diabetes Federation, and NCEP-ATP (National Cholesterol Education Program Adult Treatment Panel III) (results not shown). For more information on these definitions, please refer to the study by Vanlancker et al.[28].

Statistical significance level was set at $p < .01$ to account at least partially for multiple testing. Analyses were performed using the Statistical Package for the Social Sciences (version 24.0; SPSS) [29].

Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Results

Description of the study population

Table 1 shows the distribution of predictors and covariates stratified by adolescent's MetS risk. We observed differences in MetS risk by age groups, sex, country, alcohol intake, parent's education, and number of disadvantages (chi-square, $p < .05$). The percentage of adolescents at risk of MetS was higher for older adolescents, males, in Germany (while Sweden had the lowest risk), those who drank alcohol, those with a lower parental education, and with a higher accumulated number of disadvantages. Adolescents with a lower parental education and a nontraditional family structure had lower PA and DQI and a more frequent use of alcohol and smoking (Supplemental Table S1).

Associations between socioeconomic disadvantages and adolescent MetS risk scores or component risk scores

Table 2 presents β estimates (β) and 99% confidence intervals (CI) for models assessing the associations between the six socioeconomically disadvantaged groups and adolescent's MetS risk score. In basic-adjusted models (not adjusted for lifestyle and therefore showing total effect of social vulnerabilities mediated through lifestyle), adolescents whose mother had a low education (β .54 [99% CI .09–.98]) had a significantly higher MetS score compared to the adolescents whose mothers had a medium or high education. Also, adolescents whose fathers did not report their education level had a higher MetS score (β .74 [99% CI .01–1.48]) compared to adolescents whose fathers reported to have a medium or high education. Effect estimates were attenuated when social vulnerabilities were additionally adjusted for maternal education and family affluence (results not shown).

Table 3 presents β estimates and 99% CI results for the associations between socioeconomic disadvantages and each component of the adolescent's MetS risk score (HOMA-IR, BMI, SBP, DBP, HDL, and TG). In basic-adjusted models, adolescents with low-educated mothers had a higher HOMA-IR (β .19 [99% CI .01–.38]), and TG (β .18 [99% CI .01–.36]) and lower HDL (β −.17 [99% CI −.37, −.00]). Adolescents whose father did not report any information about their education had higher BMI (β .34 [99% CI .01–.68]).

Table 4 displays β estimates and 99% CI for the associations between the accumulated number of socioeconomic disadvantages and adolescent's MetS risk score. After adjusting for sex, age, and Tanner stage those adolescents who cumulated three to six disadvantages had a higher MetS score (β .68 [99% CI .07, 1.29]) compared to those with no disadvantages. Although similar results were found in fully adjusted models, additionally adjusting for lifestyle indicators resulted in a statistically significant association (β .72 [99% CI .04, 1.40]) between missing data on socioeconomic disadvantages and having a higher MetS risk score, compared to those with no disadvantages.

Role of lifestyle on MetS risk score

Additional analyses (results not shown) investigating the associations between lifestyle and MetS showed a positive association between DQI and MetS score and no association between alcohol/smoking and MetS. Only PA was negatively related to MetS score.

Sensitivity analyses

Our sensitivity analysis yielded similar results when having a categorical outcome instead of a continuous outcome; or when using different definitions of the MetS risk (data only shown when using the World Health Organization cutoffs) (Supplemental Tables S3–S4). Moreover, the associations between socioeconomic disadvantages and MetS risk score were stronger in male adolescents compared to female adolescents

Table 1
Description of the study population stratified by adolescent's metabolic syndrome (MetS) risk (at risk/not at risk) using World Health Organization (WHO) definition[a]

Categorical variables	N = 1,037	Metabolic syndrome (WHO definition, %)		*p*-value
	N	At risk (n = 328)	Not at risk (n = 709)	
Age groups				**.003**
12.5 to ≤ 15.0	621	31.6	68.4	
15.0 to ≤ 17.5	416	31.7	68.3	
Sex				**.010**
Male	489	35.6	64.4	
Female	548	28.1	71.9	
Country				**<.001**
Greece	98	30.6	69.4	
Germany	110	48.2	51.8	
Belgium	108	16.7	83.3	
Crete	99	42.4	57.6	
France	86	23.3	76.7	
Hungary	132	36.4	63.6	
Italy	95	35.8	64.2	
Sweden	96	22.9	77.1	
Austria	107	29.9	70.1	
Spain	106	27.4	72.6	
Tanner stage				.115
4 and 5	675	31.1	68.9	
1, 2, and 3	258	29.5	70.5	
Missing	104	40.4	59.6	
Physical activity				.488
<1 hours a day	179	35.2	64.8	
>1 hours a day (less than 6 months)	134	34.3	65.7	
>1 hours a day (more than 6 months)	634	30.6	69.4	
Missing	90	27.8	72.2	
Dietary Quality Index				.149
Low	399	28.3	71.7	
High	398	32.7	67.3	
Missing	240	35.4	64.6	
Smoking				.826
Yes	195	33.8	66.2	
Ever smoke	217	32.7	67.3	
Never smoke	605	30.6	69.4	
Missing	20	30.0	70.0	
Alcohol intake				**.008**
Yes	181	33.7	66.3	
No	599	28.0	72.0	
Missing	257	38.5	61.5	
Mother's education				**<.001**
Low	347	40.3	59.7	
Medium or high	635	27.1	72.9	
Missing	55	29.1	70.9	
Father's education				**.006**
Low	359	37.0	63.0	
Medium or high	596	27.7	72.3	
Missing	82	36.6	63.4	
Family Affluence Scale				.080
Low	316	34.4	64.6	
Medium or high	721	30.0	70.0	
Migrant status				.966
Yes	180	31.7	68.3	
No	833	31.7	68.3	
Missing	24	29.2	70.8	
Family structure[b]				.350
Nontraditional	266	35.0	65.0	
Traditional	737	30.7	69.3	
Missing	34	26.5	73.5	

(*continued on next column*)

Table 1
Continued

Categorical variables	N = 1,037	Metabolic syndrome (WHO definition, %)		*p*-value
	N	At risk (n = 328)	Not at risk (n = 709)	
Parent's employment status				.568
Unemployed	33	33.3	66.7	
Non-unemployed	882	31.2	68.8	
Missing	122	34.4	65.6	
Number of disadvantages[c]				
3–6 disadvantages	216	39.8	60.2	**.008**
2 disadvantages	183	35.5	64.5	
1 disadvantage	238	24.4	70.6	
0 disadvantages	259	25.1	74.9	
Missing	141	29.8	70.2	

In bold statistically significant differences are shown. Number of participants and percentages (%) are shown.
Chi-square tests were used to examine differences in the study population by adolescent's MetS risk (at risk/not at risk).
[a] Risk of Mets defined as having at least of one of the components of metabolic syndrome (obesity, dyslipidemia, hypertension, and glucose intolerance) using the WHO definition.
[b] Family structure: If the adolescent did not live with both biological parents, the family was defined as a "nontraditional family."
[c] A total score was calculated by adding up the scores (1 vs. 0) of the six indicators (low education of the mother, low education of the father, low family affluence (FAS), nontraditional family, migrant background, unemployed). Total score ranges from 0 (the child has none of the six disadvantages indicators) to six (the child has all six disadvantages indicators).

(results shown in Supplemental Table S5). Finally, results did not change when using family affluence as a continuous index instead of a categorical variable.

Discussion

The mother's education was the most important determinant in adolescent's cardiometabolic health, mainly due to higher levels of glucose intolerance (HOMA-IR) and dyslipidemia (TG and HDL) in case of low education. Those adolescents who did not report socioeconomic information and who accumulated three or more socioeconomic disadvantages had a higher MetS risk than adolescents who did not have any disadvantages. The associations stayed the same before and after adjustment for lifestyle.

Lifestyle-dependent versus lifestyle-independent pathway

We hypothesized there are two paths through which socioeconomic disadvantages can be associated with MetS, one direct and one indirect. The first pathway is that socioeconomic disadvantages may lead to an unhealthy, MetS increasing lifestyle [30] among others induced by stress (e.g. stress stimulated eating in the absence of hunger, that could facilitate weight gain) or (financial) priority setting. The second identifies associations independent of lifestyle: socioeconomic disadvantages can create a state of continuous stress that increases the activity of the hypothalamic-pituitary-adrenal axis leading to hypercortisolism and hence a higher MetS risk [15]. Since our associations were unchanged

Table 2
Associations between socioeconomic disadvantages and adolescent's MetS risk score. Results from the linear mixed-effects models: β estimates (β) and 99% CI results are shown[a]

	MetS risk score (basic adjustment)[b]		MetS risk score (full adjustment)[c]	
	β	99% CI	β	99% CI
Mother's education (reference group medium or high)				
Low	**.54**	**.09 to .98*****	**.55**	**.10 to 1.00*****
Missing	.18	−.70 to 1.07	.18	−.70 to 1.07
Medium or high	.00		.00	
Father's education (reference group medium or high)				
Low	.34	−.09 to .78	.35	−.09 to .79
Missing	**.74**	**.01 to 1.48*****	**.98**	**.19 to 1.77*****
Medium or high	.00		.00	
Family Affluence Scale (reference group medium or high)				
Low	.17	−.29 to .63	.21	−.26 to .67
Medium or high	.00		.00	
Migrant status[d] (reference group no migrant)				
Yes	.18	−.36 to .72	.21	−.33 to .76
Missing	−.69	−2.09 to .72	−.21	−1.90 to 1.47
No	.00		.00	
Family structure[d,e] (reference group traditional families)				
Nontraditional	.08	−.36 to .53	.08	−.37 to .53
Missing	−.23	−1.41 to .94	.25	−1.10 to 1.60
Traditional	.00		.00	
Parent's employment status[d] (reference group non-unemployed)				
Unemployed	.78	−.31 to 1.87	.86	−.24 to 1.96
Missing	.24	−.39 to .86	.29	−.35 to .92
Non-unemployed	.00		.00	

Results with *** and in bold indicate $p < .01$.
CI = confidence interval; MetS = metabolic syndrome.
[a] MetS risk score was calculated as the sum of sex- and age-specific z-scores of BMI, HOMA-IR index, mean of z-scores of diastolic and systolic blood pressure (SBP, DBP), and mean of z-score of HDL cholesterol multiplied by −1 and z-score of triglycerides (TG).
[b] Basic-models were adjusted for baseline age, sex, and Tanner stage.
[c] Full models were additionally adjusted Diet Quality Index, physical activity, smoking status, and alcohol consumption.
[d] Models additionally adjusted for classical SES indicators (maternal education and family affluence measured by FAS).
[e] Family structure: If the adolescent did not live with both biological parents, the family was defined as a “nontraditional family.”

following adjustment for lifestyle, the second lifestyle-independent pathway seems more applicable in our sample. Nevertheless, some of the lifestyle factors were associated with socioeconomic disadvantage and MetS.

Which socioeconomic disadvantages: maternal education and the accumulation

Only parents' education and particularly mother's education were linked to MetS risk. Importantly, we detected a dose-response relation as children who accumulated three to six socioeconomic disadvantages were at a higher risk of MetS than children with no disadvantages. A dose-response association related to stress and MetS has been already documented in some previous studies [31], consistent with our result.

The inverse relationship between SES and MetS in developed and developing countries has been shown in previous investigations mostly in adults [6,32]. Studies of parental SES and adolescent's MetS risk have produced contradictory results. Loucks et al. suggested that parental affluence and education were not related to the MetS in adolescents [7]. More in line with our findings, another prospective investigation concluded that family SES in childhood and adolescence was associated with MetS, impaired fasting glucose or type 2 diabetes in adulthood [8]. It is likely that knowledge, self-efficacy, or motivation towards a healthy lifestyle is more important than financial aspects since only maternal education and not parental unemployment or family affluence was a significant MetS predictor in our study.

Concerning social disadvantages, children and adolescents may not experience this stress directly but indirectly transmitted by their parents through a lack of parenting or quality time that parents could devote to them [33].

Migrant background was not a predictor of adolescent's MetS. Migrant children and adolescents have generally displayed a more sedentary way of life or adverse dietary patterns and higher levels of obesity as compared with native children, though this effect seems to disappear after adjusting for SES [34]. Moreover, lifestyle factors may act in various directions depending on the migrant origin (e.g. diet or PA may be better or worse depending on migrant origin); thus, it is difficult to have a clear hypothesis on the direction of the mediating effect of lifestyle [35].

A nontraditional family structure was also not a significant predictor of adolescent's MetS. Family structure has been suggested to be an important predictor of mental and physical health in children but less in adolescents [36,37]. When children become adolescents, they spend less time at home and peers become more important.

Table 3

Associations between socioeconomic disadvantages and each component of the adolescent's MetS risk. Fully adjusted models[b]. Results from the linear mixed-effects models: β estimates, 99% confidence intervals (99% CI) are shown[a]

	HOMA-IR z-score		BMI z-score		SBP z-score		DBP z-score		HDL z-score		TG z-score	
	β	99% CI	B	99% CI	β	99% CI	β	99% CI	β	99% CI	β	99% CI
Mother's education (reference group medium or high)												
Low	**.19**	**.01 to .38*****	.16	−.04 to .35	.07	−.09 to .33	−.01	−.18 to .16	**−.17**	**−.37 to .00*****	**.18**	**.01 to .36*****
Missisng	.17	−.19 to .62	.17	−.36 to .49	.19	−.37 to .55	−.07	−.45 to .31	−.21	−.61 to .20	.19	−.21 to .58
Medium or high	.00		.00		.00		.00		.00		.00	
Father's education (reference group medium or high)												
Low	.16	−.02 to .33	.06	−.12 to .25	.10	−.10 to .30	-.03	−.20 to .13	−.06	−.24 to .11	.12	−.05 to .30
Missing	.26	−.07 to .57	**.34**	**.01 to .68*****	.24	−.12 to .61	.03	−.26 to .34	−.29	−.62 to .03	.19	−.13 to .51
Medium or high	.00		.00		.00		.00		.00		.00	
Family Affluence Scale (reference group medium or high)												
Low	.05	−.14 to .24	.03	−.17 to .24	.16	−.05 to .38	−.01	−.19 to .17	−.06	−.25 to .13	.10	−.08 to .29
Medium or high	.00		.00		.00		.00		.00		.00	
Migrant status[c] (reference group no migrant)												
Yes	.30	−.13 to .74	.09	−.15 to .32	.01	−.21 to .23	.01	−.20 to .21	−.21	−.42 to .01	.06	−.14 to .25
Missing	−.32	−1.68 to 1.03	.03	−.70 to .76	−.05	−.74 to .63	−.26	−.90 to .37	−.08	−.77 to .61	−.09	−.80 to .62
No	.00		.00		.00		.00		.00		.00	
Family structure[c,d] (reference group traditional family)												
Nontraditional	.00	−.19 to .19	.10	−.10 to .29	-.14	−.35 to .07	−.02	−.19 to .15	−.03	−.21 to .16	−.03	−.22 to .15
Missing	.40	−.15 to .95	−.20	−.79 to .38	-.36	−.99 to .26	−.02	−.54 to .49	−.22	−.78 to .33	.05	−.50 to .60
Traditional	.00		.00		.00		.00		.00		.00	
Parent's employment status[c] (reference group non-unemployed)												
Unemployed	.27	−.18 to .72	.33	−.14 to .81	.15	−.36 to .66	.20	−.22 to .62	−.17	−.62 to .29	-.07	−.51 to .38
Missing	.03	−.23 to .30	.08	−.20 to .37	−.18	−.48 to .12	−.03	−.28 to .22	−.15	−.40 to .13	.18	−.08 to .44
Non-unemployed	.00		.00		.00		.00		.00		.00	

Results with *** and in bold indicate $p < .01$. Statistically significant results considering 99% CI are shown in bold font.

BMI = body mass index; DBP = diastolic blood pressure; HDL = high-density lipoprotein; HOMA-IR = Homeostasis Model Assessment; SBP = systolic blood pressure; TG = triglyceride.

[a] All models include random effects (school, country) to account for the study design.

[b] Models were adjusted for baseline age, sex, Tanner stage, Diet Quality Index, physical activity, smoking status, and alcohol consumption.

[c] Models additionally adjusted for classical SES indicators (maternal education and family affluence measured by FAS).

[d] Family structure: If the child did not live with both his/her parents, the family was defined as a "nontraditional family."

Table 4
Association between the accumulation of socioeconomic disadvantages and MetS risk score in European adolescents[a]. Results from the linear mixed-effects models: β estimates, 99% confidence intervals (99% CI) are shown[b]

	MetS risk score (basic adjustment)[b]		MetS risk score (full adjustment)[c]	
	β	99% CI	β	99% CI
Number of socioeconomic disadvantages[d]				
3–6 disadvantages	**.68**	**.07** to **1.29*****	**.69**	**.08** to **1.31*****
2 disadvantages	.41	−.21 to 1.02	.45	−.18 to 1.07
1 disadvantage	.20	−.36 to .76	.19	−.38 to .75
Missing	.58	−.08 to 1.24	**.72**	**.04** to **1.40*****
0 disadvantages (reference)	.00		.00	

Results with *** and in bold indicate $p < .01$.
MetS = metabolic syndrome.
All models include random effects (school, country) to account for the study design.
[a] MetS risk score was calculated as the sum of sex- and age-specific z-scores of BMI, HOMA-IR index, mean of z-scores of diastolic and systolic blood pressure (SBP, DBP), and mean of z-score of HDL cholesterol multiplied by −1 and z-score of triglycerides (TG).
[b] Basic models were adjusted for baseline age, sex, and Tanner stage.
[c] Fully adjusted models were additionally adjusted for Diet Quality Index, physical activity, smoking status, and alcohol consumption.
[d] A total score was calculated by adding up the scores (1 vs. 0) of the six indicators (low education of the mother, low education of the father, low family affluence (FAS), nontraditional family, migrant background, unemployed). Total score ranges from 0 (the child has none of the six disadvantages indicators) to six (the child has all six disadvantages indicators).

Different impact by sex

This investigation also studied whether the association between socioeconomic disadvantages and MetS in adolescents differed by sex. Some studies have shown a strong association between SES and MetS in females and less strong in males [6]. Possible mechanisms include the more severe association between SES and obesity (strongly related with MetS) in females than in males and the greater exposure to adverse psychosocial conditions such as depression and anxiety among women from low SES that in turn may lead to higher risk of MetS [38]. Our findings are in disagreement with previous literature possibly due to the higher percentage of MetS risk observed in males than in females.

Strengths and limitations

To our knowledge this is the first study to investigate the relationship between socioeconomic disadvantages and MetS risk in a large sample of European adolescents independent of lifestyle indicators. The strengths of this study include the large sample of adolescents of different ages with blood samples using a standardized methodology across the participating cities and the use of sex and age-dependent continuous and categorical MetS risk indicators based on different definitions.

This study has also some limitations. Owing to the cross-sectional design, causal conclusions cannot be inferred [39]. Missing data in some subgroups and relying on self-reports of lifestyle factors are further limitations. Dietary variables are prone to error [40] and the use of only two 24h recalls might not capture some alcohol drinking patterns such as binge drinking. Such reporting/measurement error might also be the reason for our observation of a higher DQI in those with a higher MetS risk; overweight people tend to underreport or report healthier diets [41], although it is possible that they are following a weight loss diet. Moreover, this study is not representative of each European country included although schools and classes were randomly selected allowing to represent the situation of European adolescents living in urban areas. Finally, the lack of significant results may be due to the heterogeneity of some groups in this study. For example, migrant origin and reasons for migration may be different from one person to another and nontraditional families include various situations (one-parent families, living with other relatives/friends or in institutions), and consequently some groups could be more vulnerable than others [42].

Maternal education was the most important determinant of adolescent's MetS risk independent of sex, age, Tanner stage, and lifestyle. Social vulnerabilities (migrant background, unemployment status, and belonging to a nontraditional family) were not associated with a higher MetS risk in European adolescents; however, we found a dose-response relationship between the number of social disadvantages and adolescents' MetS risk. Psychosocial stressors derived from psychosocial disadvantages can be one of the reasons to explain the higher MetS found in adolescents with low-educated mothers or with a higher accumulated number of vulnerabilities. Policy makers should focus on low-educated families and more disadvantaged groups to improve their knowledge of nutrition, exercise, and strategies to cope with stress to tackle health disparities.

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Supplementary Data

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