BREAKFAST SKIPPING AND OVERWEIGHT/OBESITY AMONG EUROPEAN ADOLESCENTS, A CROSS-SECTIONAL ANALYSIS OF THE HELENA DATASET: A DEDIPAC STUDY. [VERSION 1; REFEREES: 1 APPROVED WITH RESERVATIONS]

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**Abstract**

**Background:** The aim was to examine demographic and dietary factors associated with breakfast skipping, and the relationship of breakfast skipping with overweight/obesity among adolescents across Europe.

**Methods:** Cross-sectional data from the Healthy Lifestyle in Europe by Nutrition in Adolescence study (n=3528) conducted in ten European cities: Athens (Greece), Dortmund (Germany), Ghent (Belgium), Herkollion (Greece), Lille (France), Pecs (Hungary), Rome (Italy), Vienna (Austria), Stockholm (Sweden) and Zaragoza (Spain) were used. Analysis was carried out using a sub-sample of adolescents (n=1894) aged 12.5-17.49 years with data on breakfast skipping and two days of 24-Hour Diet Recall data. As 24-Hour Recall data was not available from Pecs (Hungary) this city was excluded. Using responses from the Food Choices and Preferences Questionnaire adolescents were classified as breakfast skippers or non-breakfast skippers. All analyses were stratified by sex. Differences in the intake of macronutrients, both overall and when breakfast was excluded, and key foods were compared.

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between skippers and non-skippers using Wilcoxon Rank Sum test. Multivariate logistic regression was used to examine the relationship between breakfast skipping and overweight/obesity.

**Results:** Overall, 44% of females were skippers compared to 36% of males. Among both male and female estimated mean fibre intake and median fruit intake were significantly lower among skippers compared to non-skippers. Male skippers were significantly more likely than non-skippers to be overweight/obese [AOR = 2.34, 95% CI, 1.40-3.90] but this was not observed among females [AOR = 0.89, 95% CI 0.59-1.34].

**Conclusions:** Different patterns of daily macronutrient intake were observed among adolescents who skip and do not skip breakfast. In males, breakfast skipping was associated with increased odds of being overweight/obese. Gender may play a key part in breakfast skipping behaviours. These results present an opportunity to identify and target adolescents who may be at risk of a poorer nutritional profile or overweight/obesity.

**Keywords**
Breakfast skipping, meal patterns, adolescents, overweight, obese, DEDIPAC

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Introduction

Breakfast consumption has been associated with a better nutrition profile and diet quality\(^1\)–\(^3\), improved cognitive function\(^1\)–\(^4\), and a lower body mass index (BMI)\(^5\)–\(^8\). The relationship of breakfast skipping with higher BMI among adolescents has been found in both cross-sectional\(^9\)–\(^11\) and longitudinal studies\(^9\)–\(^12\)–\(^14\); however, this association has not consistently been confirmed among adults\(^15\)–\(^16\). Despite the benefits of breakfast consumption, it is frequently skipped\(^17\)–\(^19\), particularly among adolescents\(^17\). A recent systematic review of meal skipping among young adults found that breakfast was the most frequently skipped meal compared to lunch and dinner\(^20\). Breakfast skipping specifically among adolescents has been associated with several unhealthy habits, including smoking\(^21\), low levels of physical activity\(^22\), decreased consumption of nutrient-rich foods, including lower intake of fruits and vegetables\(^23\), irregular meal patterns\(^23\), and an increased consumption of snacks\(^23\). Skipping breakfast has also been associated with emotional, behavioural and academic problems\(^3\).

Several demographic factors are associated with breakfast skipping, including age, sex, family structure and affluence, parental education levels and region\(^24\),\(^25\). Existing studies indicate that older children or adolescents are more likely to skip breakfast compared to younger children\(^26\)–\(^31\), girls are more likely to skip breakfast compared to boys\(^26\)–\(^31\), and that children living with a single parent may be more likely to skip breakfast compared to those with two parents\(^25\)–\(^34\). There is also evidence that suggests children of parents with lower education were more likely to skip breakfast compared to children with parents of higher education\(^25\), and low family affluence is associated with an increased likelihood of breakfast skipping\(^22\),\(^25\),\(^26\).

Existing studies are predominantly from single country studies\(^7\)–\(^12\),\(^27\),\(^28\),\(^29\),\(^31\),\(^32\). One pan-European study among children (10–12 year olds), the ENERGY (Energy balance Research to prevent excessive weight Gain among Youth) study, found that breakfast consumption varied across countries, that children who skipped breakfast were more likely to be overweight or obese, and this relationship was similar but the magnitude differed across countries\(^30\)–\(^34\). Furthermore, existing studies do not often adjust for many potential predictors of obesity, including diet, physical activity and sedentary behaviour. To our knowledge the relationship between breakfast skipping and overweight/obesity has not been explored among adolescents across Europe. Therefore, the objectives of the current study were to (1) determine the prevalence of breakfast skipping among European adolescents (2) examine the demographic factors and dietary patterns associated with breakfast skipping in European adolescents, (3) examine differences in macronutrient and food intakes between breakfast skippers and non-skippers, and (4) determine whether breakfast skipping is associated with overweight/obesity.

Methods

Study design and sampling

The Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study is a cross-sectional, school-based study of European adolescents aged 12.5–17 years, from 10 European cities: Athens in Greece, Dortmund in Germany, Ghent in Belgium, Heraklion in Greece, Lille in France, Pecs in Hungary, Rome in Italy, Stockholm in Sweden, Vienna in Austria and Zaragoza in Spain\(^35\). A random cluster sampling stratified by geographic location, social economic status (SES) and age of the population was used. The study was performed and approved by ethical guidelines of the Declaration of Helsinki. The HELENA study protocol was approved by the national or local independent ethical committee from the relevant European city. All participants and their parents signed an informed consent form\(^35\). Data on nutrition and health-related factors was collected during the academic year 2006–2007. A more detailed description of the study design, sampling and procedure has previously been published\(^35\). Adolescents who did not have two 24 Hour Dietary Recall (24-HDR) were excluded from the current analysis. As 24-HDR data was not available from Pecs (Hungary) this city was excluded. Under-reporters were included in the current analysis but analysis was also carried out with just plausible reporters. Underreporting was defined as having an individual ratio of energy intake divided by the estimated basic metabolic rate lower than 0.96\(^35\).

Breakfast skipping

Several studies\(^2\),\(^3\),\(^17\),\(^27\) have highlighted that some variation exists in terms of how breakfast consumers or skippers are defined. As it was felt to better reflect habitual dietary behaviour the ‘Food Choices and Preferences’ questionnaire (preferences questionnaire; not yet publically available) was used to classify adolescents according to breakfast consumption. The breakfast question from the questionnaire has previously been used to assign consumers and skippers and the test–retest stability has been measured with the dichotomized breakfast statement “I often skip breakfast” showing good agreement between the test and retest (0.91)\(^25\). Adolescents were classified as skippers or non-breakfast skippers on the basis of their response to the following question ‘I often skip breakfast’. Adolescents were asked to indicate to what degree they agreed with the statement on a seven-point scale, with ‘strongly disagree’ scored as a 1, and ‘strongly agree’, scored as a 7. A breakfast skipping variable was created using this data, recoded into three categories. Those who scored the statement with 5 ‘slightly agree’, 6 ‘moderately agree’, or 7 ‘strongly agree’ were coded as a ‘skipper’. Those who scored the statement with a 1 ‘strongly disagree’, 2 ‘moderately disagree’, or 3 ‘slightly disagree’ were coded as a ‘non-breakfast skippers’ and those who scored the statement with a 4 ‘neither agree nor disagree’ were excluded as they could not be assigned to either group. The term ‘breakfast’ was left open to interpretation by the adolescents themselves.

As there is no agreed definition of breakfast skipping, and the classification used may differ between studies, we used the two non-consecutive 24-HDR to classify ‘skippers’ (those who consumed breakfast on one day, or neither day) and ‘non-skippers’ (those who consumed breakfast on both days), and examined the correlation with our classification using the preferences questionnaire.

Body mass index (BMI)

Weight and height were measured following standard procedures\(^36\) and BMI (kg/m\(^2\)) was calculated as body mass (in kilograms) divided by the square of height (in metres). BMI...
was categorized following the International Obesity Task Force criteria\(^5\). For the purpose of this analysis, a binary variable with the categories ‘underweight/normal’ and ‘overweight/obesity’ was created.

**Socio-demographic variables**

The association of breakfast skipping with the following socio-demographic variables was examined: region, age, family affluence scale (FAS), maternal education and family structure. Study centres were categorized into three regions: northern (Sweden and Belgium); central (France, Germany and Austria); and southern (Greece, Italy and Spain). Age was recoded into two categories < 15 years and ≥ 15 years.

Family Affluence Scale (FAS) measures the material conditions in the family. A modified youth-specific scale was used\(^6\). The original variable was scored on an eight-point scale, based on number of cars, computers, own bedrooms and internet access in the household. For this analysis, FAS was recoded as a binary variable categorised as either ‘low family affluence’ or ‘high family affluence’. Those where FAS was scored as 0, 1, 2, or 3 were categorised as ‘low family affluence’ and where FAS was scored as 4, 5, 6 or 7 were categorised as ‘high family affluence.’

Maternal education was reported as ‘lower education’, ‘lower secondary education’, ‘higher secondary education’ or ‘higher education or university degree’. For the purpose of this analysis, maternal education was recoded into three categories: ‘lower’ (‘lower education’, ‘lower secondary education’), ‘higher secondary education’ and ‘higher education or university degree’.

Adolescents were categorised as a ‘traditional family’ if they answered yes to ‘living with both your parents’, ‘living with your mother and her partner’ or ‘living with your father and his partner’. Adolescents were categorised as ‘single parent or shared care families’ if they answered ‘with your mother’, ‘with your father’, ‘with your grandparents or relatives’, ‘with foster or adoptive parents’ or ‘in an orphanage or somewhere else’.

**Diet and physical activity**

**Diet Quality Index**

A Diet Quality Index (DQI) was developed based on information from the two non-consecutive 24-HDRs. These recalls were based on data collected by a computer-based self-administered tool, the HELENA-Dietary Intake Assessment Tool. The tool examined six meal occasions including breakfast, morning snack, lunch, afternoon snack, evening meal and evening snack. Adolescents were requested to recall types and quantity of foods and beverages consumed. These foods were then transferred into nutrients using the German Food Code and Nutrient Data Base. The Multiple Source Method was used to estimate dietary intake of nutrients and foods taking into account personal variability and correcting for demographics including age, sex and study centre\(^7\). The DQI consists of three fundamentals assessing diet: quality, diversity and equilibrium. The development and validation of the DQI has been described in detail elsewhere\(^6\). Higher scores reflect higher dietary quality. For the purpose of this analysis mean DQI was examined between breakfast skippers and non-breakfast skippers.

**Macronutrients & food groups**

Intakes of energy, macronutrient (fat, saturated fat, protein and carbohydrates, fibre) and sodium in grams per day, based on the 24-HDR were examined between skippers and non-breakfast skippers. Overall macronutrient intake (all meals) and intake excluding the breakfast meal were examined between the two groups.

Intakes of specific food groups among skippers and non-breakfast skippers were examined: vegetables, fruit and vegetable juice, dairy snacks, chocolate; cakes, pies, and biscuits; confectionary non-chocolate, other sugary products, and sugar sweetened beverages. The group ‘sugar foods’ was created by combining chocolate; cakes, pies and biscuits; confectionary non-chocolate, other sugary products, and sugar sweetened beverages.

**Physical activity**

Physical activity was based on adolescents’ self-reported responses to the International Physical Activity Questionnaire for Adolescents (IPAQ-A) (Supplementary File 1) which assessed four categories of physical activity including: school related physical activity, transportation, housework and leisure\(^8\). Physical activity was classified as high (greater than or equal to 3000min/week), moderate (600 up to 3000min/week) and low (less than 600 min/week). These cut off points were based on guidelines for data processing and analysis of IPAQ\(^8\).

**Study tools**

Questionnaires and study tools will progressively be made publicly available via the HELENA study website. A copy of the IPAQ-A questionnaire has been provided as Supplementary File 1.

**Statistical analysis**

Analysis was conducted using Stata SE version 13.1. In order to explore sex differences all analyses presented were stratified by sex. Differences in breakfast skipping according to socio-demographic variables (age, region, maternal education, FAS and family structure) and lifestyle behaviours (physical activity and diet quality) were explored using Pearson’s chi square test. Differences in the daily intake of overall nutrients, and nutrients excluding breakfast according to breakfast skipping were explored using the Wilcoxon Rank-Sum test stratified by sex. Estimated mean intakes of macronutrients among skippers and non-skippers were calculated using the generalized linear models and using the margins command, adjusting for covariates which were found to be significantly associated with breakfast skipping. The high number of adolescents with zero intake for specific food groups, meant that these variables were highly skewed and estimated mean intakes were not calculated as a result. Crude intakes are reported for these variables.

Multivariate logistic regression was used to examine the relationship between breakfast skipping and overweight/obesity.
Regression models were adjusted for demographic variables (region, age, maternal education, FAS, and family structure) and lifestyle factors, including physical activity and diet quality (DQI). The analysis was adjusted for clustering by school using the svy command. Additionally, a separate analysis was conducted stratified by each of 8 HELENA centres (Greece, Germany, Belgium, France, Italy, Sweden, Austria, and Spain), adjusting for region, age, sex, maternal education, FAS, and family structure. Finally, as a sensitivity analysis we investigated whether similar associations between breakfast skipping and overweight/obese were observed if respondents were classified as breakfast skippers based on the 24-HDR i.e. respondents did not report having breakfast on one or both 24-HDR days.

Results
Profile of breakfast skippers and breakfast consumers
Excluding those missing one day of 24-HDR (n=1198), and adolescents who were neither breakfast skipper nor non-breakfast skipper (n = 150), or those who were missing data on breakfast skipping (n = 286), left an analysis sample of 1894 adolescents; 1775 of which had available data on all covariates of interest. Overall 40.3% of adolescents were skippers (n = 764). Across the eight countries the proportion of breakfast skippers ranged from 52.7% (Greece and Austria) to 21.5% (Spain). Among males, breakfast skipping ranged from 52.0% (Austria) to 15.9% (Spain), whereas among females, it ranged from 61.6% (Greece) to 26.3% (Sweden) (Table 1). When two different classification approaches were compared (using Preferences questionnaire or 24-HDR), 15.5% (n = 118) of skippers did not report eating breakfast on both 24-HDR days; this was 1.0% (n=11) among non-skippers. Using the alternative classification, only 6.8% (n=129) of adolescents could be classified as skippers; 6.3% of males (n=53) and 7.2% of females (n=76).

Table 2 shows the profile of male and female skippers and non-skippers. A significantly larger proportion of females were skippers compared to males (Pearson's chi square test: p <0.01). Among male skippers, there were a higher proportion of younger adolescents (≥15 years) and from the Central or Southern regions of Europe compared to non-skippers (p<0.001). Among females, there were a greater proportion of skippers with low FAS score and from the Central or Southern region, and with mothers of lower education level compared to non-skippers (p<0.001). Prevalence of overweight/obesity was higher among male skippers than non-skippers (32.8% vs. 18.4%).

Energy, macronutrient and food intakes among skippers and non-skippers
Median (IQR) DQI was significantly higher among skippers than non-skippers; this was true of both males [53.8 (21.4) vs. 45.4 (26.8)] and females [58.3 (18.6) vs. 53.4 (24.9)] (p<0.001). Table 2 shows macronutrients and food group intake among male and female breakfast skippers and non-skippers.

Nutrients. Nutrient intakes among skippers and non-skippers were described as estimated means (Table 3). Fibre mean intake was lower among both male (p <0.001) and female (p <0.001) skippers compared to non-skippers. Among females, energy intake for the day was lower among skippers than non-skippers (p<0.001), as was intake of fat and saturated fat and protein (p<0.001).

Energy intake from nutrients was also examined among skippers and non-skippers according to meal (Supplementary Table 1). Among females, skippers had significantly higher intakes of energy overall (p<0.001) and saturated fat (p<0.001) from their afternoon snack. They also had higher energy from protein (p<0.01) from their morning snack compared to non-skippers.

Food groups. Among both males (p<0.001) and females (p<0.001) skippers had a lower intake of fruit compared to non-skippers (Table 3). Consumption of the four food groups ‘cakes, pies, & biscuits’, ‘chocolate’, ‘other sugar products’, and ‘confectionary non-chocolate’, and the composite group ‘sugar foods’ was low overall and there were no significant differences in intakes among skippers and non-skippers among either males or females.

Table 1. Breakfast skipping across eight HELENA centres.

| Centre              | Male (n=839) | Female (n=1055) |
|---------------------|-------------|-----------------|
|                     | Skipper (n=302) | Non-skipper (n=537) | Skipper (n=462) | Non-skipper (n=593) |
| Greece (Athens)     | 39(41.1)    | 56(58.9)        | 77(61.6)        | 48(38.4)            |
| Germany (Dortmund)  | 71(44.9)    | 87(55.1)        | 49(42.2)        | 67(57.8)            |
| Belgium (Gent)      | 25(22.1)    | 88(77.9)        | 52(38.5)        | 83(61.5)            |
| France (Lille)      | 20(25)      | 60(75)          | 49(40.5)        | 72(59.5)            |
| Italy (Roma)        | 37(43)      | 49(57)          | 78(52.7)        | 70(47.3)            |
| Sweden (Stockholm)  | 20(23.3)    | 66(76.7)        | 44(27.8)        | 114(72.2)           |
| Austria (Vienna)    | 79(52)      | 73(48)          | 92(53.5)        | 80(46.5)            |
| Spain (Zaragoza)    | 11(15.9)    | 58(84.1)        | 21(26.3)        | 59(73.8)            |
Breakfast skipping and overweight/obesity

Among males, breakfast skippers had significantly increased odds of being overweight/obese compared to regular non-breakfast skippers in the unadjusted model [Odds Ratio (OR), 2.10, 96% CI, 1.37-3.22] (Table 4). This association remained in the full model after including region, age, maternal education, FAS, family structure, physical activity, diet quality and energy intake as covariates [Adjusted Odds Ratio (AOR), 2.34, 95% CI, 1.40-3.90]. Among females, there was no significant association between breakfast skipping and overweight/obesity. Among males, those whose mothers had higher education or a university degree were less likely to be overweight/obese compared with those whose mothers had a lower education level (AOR, 0.42, 95% CI 0.19-0.52). This was also true of female adolescents (AOR, 0.33, 95% CI, 0.21-0.51). Among males, adolescents from Southern regions were more likely to be overweight/obese compared with those from the Northern regions (AOR 1.57, 95% CI, 1.04-2.36).

The relationship between breakfast skipping and overweight/obese was also examined by country (Supplementary Table 2). This suggested the direction and level of effect may not be consistent across the eight countries; for example, in Spain and Sweden, breakfast skipping did not appear to increase the odds of overweight/obese. However, none of these associations were significant.

A different relationship was found when the regression analysis was performed using the alternative (24-HDR) classification.

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### Table 2. Demographic profile of breakfast skippers and non-skippers stratified by sex.

|                    | Male (n = 839) | Female (n = 1055) |
|--------------------|---------------|-------------------|
|                    | Skipper (n = 302) | Non-skipper (n = 537) | Skipper (n = 462) | Non-skipper (n = 593) |
| **N (%)**          | **N (%)**     | **N (%)**         | **N (%)**      | **N (%)**          |
| **Age**            |               |                   |               |                   |
| Age < 15 years     | 132(43.7)     | 311(57.9)         | 251(54.3)     | 341(57.5)         |
| Age ≥ 15 years     | 170(56.3)     | 226(42.1)         | 211(45.7)     | 252(42.5)         |
| **Region**         |               |                   |               |                   |
| North              | 136(45)       | 301(56.1)         | 194(42)       | 336(56.7)         |
| Central            | 79(26.2)      | 73(13.6)          | 92(19.9)      | 80(13.5)          |
| South              | 87(28.8)      | 163(30.4)         | 176(38.1)     | 177(29.8)         |
| **Mother’s education** |               |                   |               |                   |
| Lower/Lower Secondary Education | 104(37) | 146(28.6) | 155(34.8) | 148(26.1) |
| Higher secondary education | 89(31.7) | 150(29.4) | 168(37.8) | 172(30.4) |
| Higher education/ university degree | 88(31.3) | 215(42.1) | 122(27.4) | 246(43.5) |
| **Family affluence scale** |               |                   |               |                   |
| Low                | 70(23.3)      | 110(20.6)         | 142(30.7)     | 113(19.1)         |
| High               | 231(76.7)     | 425(79.4)         | 320(69.3)     | 479(80.9)         |
| **Family structure** |               |                   |               |                   |
| Traditional family | 217(72.6)     | 423(80.6)         | 358(79.9)     | 468(80.7)         |
| Single parent/shared-care families | 82(27.4) | 102(19.4) | 90(20.1) | 112(19.3) |
| **BMI**            |               |                   |               |                   |
| Underweight/Normal | 203(67.2)     | 438(81.6)         | 362(78.4)     | 494(83.3)         |
| Overweight/Obese  | 99(32.8)      | 99(18.4)          | 100(21.6)     | 99(16.7)          |
| **Physical activity** |              |                   |               |                   |
| Low                | 80(28.8)      | 136(26.9)         | 144(33)       | 173(31.4)         |
| Moderate           | 187(67.3)     | 344(68.1)         | 281(64.3)     | 370(67.2)         |
| High               | 11(4)         | 25(5)             | 12(2.7)       | 8(1.5)            |

*Indicates significant between skippers and non-skippers (p<0.001) for males
†Indicates significant between skippers and non-skippers (p<0.001) for females

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Table 3. Estimated mean intake of macronutrients of breakfast skippers and non-skippers adjusted for age, region, maternal educations, family structure and BMI and stratified by sex*

|                  | Male (n=839) | Female (n=1055) |
|------------------|--------------|-----------------|
|                  | Skipper (n=302) | Non-skipper (n=537) | Skipper (n=462) | Non-skippers (n=593) |
| **Energy (kcal/day)** |              |                  |              |                  |
| Energy           | 2463 (2334,2591) | 2625 (2530,2719) | 1751 (1682,1820) | 1963 (1902,1682) |
| Energy exc. breakfast | 2151.9 (2035,2269) | 2124 (2038,2209) | 27 (25,28) | 31 (29,32) |
| **Nutrients (g/day)** |              |                  |              |                  |
| Fat              | 92 (86, 98) | 92 (92, 101) | 64 (70, 77) | 74 (71, 77) |
| Fat exc. breakfast | 81 (75, 86) | 80 (76, 84) | 57 (54, 60) | 61 (58, 64) |
| Saturated fat    | 38 (39, 43) | 41 (39, 43) | 27 (25,28) | 31 (29,32) |
| Saturated fat exc. breakfast | 32 (30, 35) | 33 (31, 34) | 23 (22,24) | 24 (23,26) |
| Protein          | 98 (93, 100) | 104 (100, 108) | 68 (65,71) | 78 (75,81) |
| Protein exc. breakfast | 89 (84, 95) | 89 (85, 93) | 61 (58, 64) | 66 (64, 69) |
| Carbohydrates    | 299 (282,316) | 323 (311,336) | 219 (210,228) | 240 (232,248) |
| Carbohydrates exc. breakfast | 257 (241,272) | 253 (242,264) | 187 (179,195) | 185.9 (179,193) |
| Fibre            | 18 (17, 20) | 22 (21,23) | 16 (15,16) | 19 (18,20) |
| Fibre exc. breakfast | 16 (15, 17) | 18 (17, 18) | 14 (13, 15) | 15 (15, 16) |
| Sodium           | 2 (2, 3) | 3 (3, 3) | 2 (2, 2) | 2 (2, 2) |
| Sodium exc. Breakfast | 2 (2, 2) | 2 (2, 3) | 2 (2, 2) | 2 (2, 2) |
| **Food groups (g/day)** |              |                  |              |                  |
| Vegetables       | 51 107 | 75 122 | 60 105 | 76 108 |
| Fruit            | 65 155 | 95 193 | 70 159 | 118 165 |
| Fruit & vegetable juice | 0 200 | 100 265 | 75 200 | 100 225 |
| Sugar foods† | 0 0 | 0 0 | 0 0 | 0 0 |
| Savoury snacks   | 0 0 | 0 0 | 0 0 | 0 0 |

Abreviations: BMI = Body Mass Index; IQR = Interquartile Range; CI = Confidence Interval; Exc= excluding

*significant results are highlighted in bold
†sugar foods defined as chocolate; cakes, pies, biscuits; other sugar products; confectionary non-chocolate, and sugar-sweetened beverages

Discussion
Key findings
The aim of this study was to describe the demographic and dietary patterns associated with breakfast skipping among European adolescents, and to explore the association between habitual breakfast skipping and being overweight or obese.
**Table 4. Multivariate logistic regression showing the association between breakfast skipping, demographic factors, physical activity, diet quality and overweight/obesity among male and female adolescents (n = 1471)**.

|                | Males (n = 673) | Females (n = 798) |
|----------------|-----------------|-------------------|
|                | Unadjusted      | Adjusted          | Unadjusted      | Adjusted          |
|                | OR  95% CI      | p                 | OR  95% CI      | p                 |
| Breakfast skipping |                 |                   |                 |                   |
| Non-skipper    | 1.00 [1.00,1.00] | 1.00 [1.00,1.00]  | 1.00 [1.00,1.00] | 1.00 [1.00,1.00]  |
| Skipper        | 2.10 [1.37,3.22] | 0.00 [2.34,3.90]  | 1.30 [0.99,1.71] | 0.06 [0.89,1.34]  |
| Region         |                 |                   |                 |                   |
| North          | 1.00 [1.00,1.00] | 1.00 [1.00,1.00]  | 1.00 [1.00,1.00] | 1.00 [1.00,1.00]  |
| Central        | 1.75 [0.84,3.65] | 0.12 [1.43,2.47]  | 0.18 [0.44,2.99] | 0.99 [0.31,1.62]  |
| South          | 1.88 [1.16,3.02] | 0.01 [1.57,2.36]  | 0.03 [1.98,3.74] | 0.04 [1.69,3.59]  |
| Age            |                 |                   |                 |                   |
| < 15 yr        | 1.00 [1.00,1.00] | 1.00 [1.00,1.00]  | 1.00 [1.00,1.00] | 1.00 [1.00,1.00]  |
| ≥15 yrs        | 0.91 [0.61,1.34] | 0.60 [0.85,1.26]  | 0.39 [0.61,1.39] | 0.68 [0.65,1.37]  |
| Maternal education |             |                   |                 |                   |
| Lower/Lower Secondary Education | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] |
| Higher secondary education | 0.82 [0.54,1.27] | 0.35 [0.62,1.06] | 0.08 [0.83,0.91] | 0.28 [0.51,1.12]  |
| Higher education/ university degree | 0.42 [0.26,0.68] | 0.00 [0.32,0.52] | 0.00 [0.19,0.61] | 0.33 [0.21,0.51]  |
| FAS            |                 |                   |                 |                   |
| Low family affluence | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] |
| High family affluence | 0.71 [0.47,1.08] | 0.11 [1.04,1.66] | 0.87 [0.45,0.93] | 0.83 [0.55,1.24]  |
| Family structure |         |                   |                 |                   |
| Traditional family | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] |
| Single-parent/ shared-care families | 1.31 [0.80,2.15] | 0.26 [1.14,1.91] | 0.59 [1.15,2.15] | 0.64 [1.20,5.26]  |
| Physical activity | 1.00 [1.00,1.00] | 0.32 [1.00,1.00] | 0.82 [1.00,1.00] | 0.87 [1.00,1.00]  |
| Diet quality (DQI quintiles) | |                   |                 |                   |
| 1              | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] | 1.00 [1.00,1.00] |
| 2              | 0.70 [0.33,1.48] | 0.32 [0.76,1.44] | 0.37 [0.92,1.50] | 0.71 [0.49,2.08]  |
| 3              | 0.78 [0.46,1.32] | 0.33 [0.86,1.64] | 0.63 [0.84,2.26] | 0.19 [0.66,3.17]  |
| 4              | 0.97 [0.56,1.69] | 0.91 [1.35,2.24] | 0.23 [0.45,2.54] | 0.87 [0.31,2.58]  |
| 5              | 1.41 [0.80,2.49] | 0.22 [1.90,4.46] | 0.11 [0.70,3.12] | 0.28 [1.47,5.63]  |
| Energy intake  | 1.00 [1.00,1.00] | 0.00 [1.00,1.00] | 0.00 [1.00,1.00] | 0.00 [1.00,1.00]  |

Abbreviations: IQR = Interquartile Range; CI = Confidence Interval

*adjusted for region, age, maternal education, FAS, and family structure, physical activity, diet quality and daily energy intake; significant results are highlighted in bold
There were a number of key findings. Firstly, a high proportion of adolescents (40.3%) were classified as skippers, ranging from 52.8% (Austria) to 21.5% (Spain), with a higher proportion of skippers among females (43.8%) compared with males (36.0%). Secondly, in terms of demographics, among males, there were higher proportions of skippers among older age groups, and those living in Southern Europe. Among females, there were greater proportions of skippers among those with lower family affluence, with mothers of lower education. Thirdly, both male and female adolescents who skipped breakfast had significantly lower diet quality overall, and lower intake of fibre and fruit. In terms of meal-specific intakes, female skippers derived more energy from protein (p<0.001) from their morning snack than non-skippers. Finally, male breakfast skippers were more than three times more likely to be overweight/obese compared to regular breakfast consumers after adjustment for demographic and lifestyle factors. Among females we found no significant association between skipping breakfast and overweight/obesity. Among both male and female adolescents, lower maternal education was significantly associated with overweight/obesity.

While the range in terms of the prevalence of breakfast skipping across the eight countries was not as great as that reported among children of the ENERGY study\textsuperscript{14}, this could reflect the different age group, the selection of countries sampled, and the approach used to determine skippers i.e. in the ENERGY study breakfast skippers were those who skipped breakfast at least once during weekdays and/or weekends. However, the variation between countries in the current study does suggest that some cultural differences in patterns of breakfast skipping, or in the interpretation of the breakfast meal, may exist. It could also reflect the fact that the term “breakfast” was left open to interpretation by adolescents themselves. The prevalence of skippers in our study was at the higher end of previously reported estimates of skipping among children and adolescents (10–30%)\textsuperscript{1}. This variation may reflect an on-going issue with research in this area\textsuperscript{43}, namely, the different approaches used to classify breakfast skippers across studies, which makes cross-study comparisons difficult. The current study findings suggest that different approaches to classify skippers, even within the same study, do not classify adolescents consistently, and indicate a different relationship between skipping and BMI may exist depending on the approach used. A further issue with research in this area, not unique to this study, is the fact that no established definition of breakfast exists, although the academic standard is outlined as: “first meal of the day, eaten before or at the start of daily activities (e.g., errands, travel, work), within 2 h of waking, typically no later than 10:00 in the morning, and of an energy level between 20 and 35% of total daily energy needs”\textsuperscript{44}. However, as highlighted by Rampersaud et al.\textsuperscript{3}, the definition of breakfast consumption can be based on consumption on a designated day or number of days, habitual intake, or based on intake within a certain time frame\textsuperscript{45}, or before a certain event e.g. preceding school\textsuperscript{46}. Unless definitions are made explicit, it is important to allow for differences in the interpretation of breakfast among study participants. In the current study ‘breakfast’ was left open to interpretation by the adolescents themselves, and it is possible that there may be differences in understanding even between adolescents within the study about what constitutes a breakfast meal. For example, some may consider it a meal eaten immediately after waking in the morning or a snack eaten in late morning after arrival at work or school, and this could have affected individuals’ responses. Variation in the types of food groups consumed in morning may have also influenced whether adolescents would report themselves as skipper or non-skipper.

The high proportion of skippers among females fits with existing evidence suggesting sex differences in dietary behaviours\textsuperscript{44}, including meal and breakfast skipping\textsuperscript{31,24,26,27}. However, some studies have found skipping is higher among males\textsuperscript{30}, with another pan-European study finding no significant difference in prevalence between girls and boys\textsuperscript{31}. The current findings on socio-demographics and breakfast skipping are also consistent with previous work from the US\textsuperscript{46} and Netherlands\textsuperscript{37}, indicating breakfast skipping is more common among older children, and with research from other pan-European studies, which show an association of skipping with lower family affluence\textsuperscript{34}, living with a single-parent family\textsuperscript{38}, and lower parental education\textsuperscript{41}. The association of overweight/obesity among adolescents with mothers of lower education is consistent with existing work\textsuperscript{40}, including that from the ENERGY study\textsuperscript{14}, which suggests this relationship may be attributed to the poorer dietary and physical activity patterns observed in those with parents of lower education. Previous work also shows breakfast skipping appears to cluster with other unhealthy dietary behaviours\textsuperscript{5,21} and that skippers may have lower intake of several important nutrients\textsuperscript{46}. The lower diet quality, and lower intake of fruit and fibre identified among male and female skippers in the current study may suggest that adolescents who habitually skip breakfast are missing key nutritional elements through skipping the breakfast meal, or, alternatively, that the breakfast skipping behaviour may be a marker of irregular dietary behaviours.

In spite of the different approaches used to classify skippers across studies (including the use of questionnaires to assess frequency of intake per week) the current findings are consistent with existing work which show an association between breakfast skipping and higher BMI\textsuperscript{3,18,42}, including a systematic review of studies across Europe\textsuperscript{6}. However, the current study differs to others in examining the relationship by sex, and finding this association is significant among males only. Even if we cannot assert that breakfast skipping itself leads to an adolescent becoming overweight or obese, the behaviour may be a marker, both for higher BMI, and a poorer diet. Examining differences in nutrient and food intakes between skippers and non-skippers can provide some insight into how the behaviour may contribute to a higher BMI. While the lower intakes of fibre and fruit identified among skippers can be somewhat expected, given that high-fibre cereals and fruit may be considered ‘breakfast foods’, the fact that skippers did not appear to compensate for these deficiencies during the day has implications for their overall nutritional intake. Previous work
suggests that daily energy intake may be compensated among skippers by greater consumption of more energy-dense foods, for example those high in carbohydrates, over the rest of the day, or from higher consumption during a morning snack\textsuperscript{38}; a pattern observed in the current study.

Implications

European adolescents, both male and female, who skip breakfast have poorer diets, and, if male, are more likely to also be overweight/obese. The fact this behaviour is associated with a poorer diet and higher BMI should be a cause for concern, given the risk of these habits tracking into adulthood\textsuperscript{14}. The greater predominance of skipping among certain demographics (older adolescents from certain regions, females, or those from families with lower socio-demographic status), presents a key opportunity to identify and target adolescents who may be at risk of breakfast skipping which may serve as a proxy of unhealthy eating behaviours, and overweight/obesity. There is scope to raise awareness about adolescents who may be particularly vulnerable, most likely to engage in this behaviour, and to target interventions appropriately.

The sex-specific association reported in the current study could in some way be indicative of different motivations for engaging in breakfast skipping between male and females. Male and female adolescents may have different reasons for engaging in breakfast skipping, and the role of gender in breakfast skipping needs to be better understood. A recent systematic review of factors which influence meal skipping among young adults, cited a perceived lack of time, weight control, money, and habit among the main correlates of skipping\textsuperscript{20}. Interventions to address the behaviour may benefit if they are designed as appropriate to male and female adolescents. To inform intervention development, qualitative work would be needed to fully understand any sex differences, the specific motivations for breakfast skipping, and other contextual factors which could impact on the behaviours in these groups.

Strengths and limitations

One of the strengths of this study is the use of a large pan-European dataset representing adolescents across ten European Cities, and eight countries. Few studies have examined breakfast skipping behaviours in pan-European samples, and, to our knowledge this is the first study to examine the association between skipping and overweight/obesity among adolescents across different countries in Europe, taking into account the role of several key confounding factors (age, region, maternal education, FAS, family structure, physical activity, diet quality, and energy intake). This is also the first study to examine adjusted differences in nutrient intakes among skippers and non-skippers. Furthermore, food and nutrient intake was collected using a validated instrument, the computerised 24-HDR, HELENA-DIAT\textsuperscript{38}. Although data collected from the preferences questionnaire and I-PAQ were self-reported, FAS and I-PAQ have been validated in other studies\textsuperscript{11,47}. The study is strengthened by the use of the self-report preferences questionnaire to classify breakfast skippers, which was felt to better represent habitual dietary behaviours. However, the study has some limitations. It should be noted that the data were collected during the academic year 2006–2007 and are now 10 years old. It is possible that dietary patterns among adolescents may have changed since the original study was conducted. Although a high proportion of the sample were classified as breakfast skippers, this may reflect the crude approach used to dichotomize adolescents as skippers or non-skippers according to agreement with the statement ‘I often skip breakfast’. Any level of agreement, be it ‘slightly’, ‘moderately’ or ‘strongly’, was taken as an indication of breakfast skipping, and it should be highlighted that it is uncertain how well the interpretation aligns with adolescents’ preferences. For example, does slight agreement also imply slight disagreement with the statement? Furthermore, there may be different interpretations of the word ‘often’ used in the breakfast skipping question. Comparing the classification approach to that using the 24-HDR, some discrepancies were observed, which may reflect the fact that the 24-HDR only includes two days (one weekday, one weekend), and this ‘actual’ behaviour or ‘snapshot’ may not align with participants’ habitual behaviour. This discrepancy further suggests the need for a more standardised approach to defining breakfast skipping which would allow for more comparable results across studies. The current study is limited by its cross-sectional design, and the findings reported here would ideally be confirmed through a longitudinal study. Overweight or obese adolescents may be likely to skip breakfast rather than becoming overweight through skipping and poor dietary intake. A longitudinal study among 9-14 year olds by Berkey et al. in the US\textsuperscript{14} found that breakfast skipping appears to have a different effect according to baseline weight status. Over a year of follow-up, children who were overweight and who skipped breakfast lost weight whereas normal weight children who skipped breakfast gained weight relative to normal weight children who ate breakfast regularly.

Conclusion

This study found that skipping breakfast is a behaviour associated with a poorer diet and overweight/obesity among males, which may be more common among those from low socio-demographic backgrounds. The results show breakfast skipping among males is associated with overweight/obesity; gender may play a key part in breakfast skipping behaviours. These results present an opportunity to identify and target adolescents who may be at risk of a poorer nutritional profile or overweight/obesity. Interventions to target breakfast skipping should potentially be sex-specific and account for different motivations for the behaviour among male and female adolescents. Identification of meal patterns, and developing a better understanding their determinants, has the potential to inform the development of targeted interventions to address this important public health issue.

Data availability

The HELENA dataset is available to access subject to submission and approval of a study proposal by Professor Luis Moreno (lmoreno@unizar.es) at the University of Zaragoza.
Competing interests
No competing interests were disclosed.

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The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Supplementary material
Supplementary File 1: IPAQ questionnaire
Click here to access the data.

Supplementary Table 1: Intake of energy (g/day) derived from macronutrients by meal* among breakfast skippers and non-skippers stratified by sex
Click here to access the data.

Supplementary Table 2: Multivariate logistic regression showing the association between breakfast skipping and overweight/obese across eight countries (n = 1471)
Click here to access the data.

Supplementary Table 3: Multivariate logistic regression showing the association between breakfast skipping and overweight/obese among male and female adolescents (n = 1894)
Click here to access the data.

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This paper describes a cross-sectional analysis of associations of between breakfast skipping, defined using two separate approaches, with prevalence of overweight/obesity in a large multinational sample of European adolescents. While many observational studies have previously examined associations between breakfast skipping and obesity in children and adolescents, this study adds to the literature by providing a thorough exploration of correlates of breakfast skipping in a sample of adolescents drawn from different geographical locations across Europe. This study thus provides some potential insights into cultural diversity in relation to meal skipping behaviours. A key strength of this study is that it compares two different approaches to classify participants as breakfast skippers and the implications of this are appropriately highlighted in the discussion. Another strength is the use of two 24-h dietary recalls and the MSM method to determine usual intakes of foods and nutrients. A limitation of the study relates to the ambiguity of the interpretation of the questionnaire item used to determine prevalence of habitual breakfast skipping, however, the authors clearly address this concern in the limitations and strengths section of the discussion.

Overall, this paper is very clearly written and well conducted, however, I do have some queries and comments in relation to the analysis and presentation of results.

Major comments

Methods
1. Please provide (either here or at the beginning of the results section) the total number of HELENA participants, the study response rate and whether the study response rate varied substantially by country. While the use of two 24-h recalls is a strength of the present study, this comes at a cost of losing 1198 participants (~34% total sample) who completed one 24-h recall. The authors therefore need to address the potential bias that may have been introduced by excluding these participants. I suggest conducting further sensitivity analysis that examines differences between those who were included/excluded in relation to key variables (sociodemographic position, BMI, breakfast skipping – questionnaire data and based on 1-24 h recall). This issue should also be addressed in the limitations section of the discussion.

Results
1. Table 3: Reported energy intake differs between breakfast skippers and non-skippers. I would find it useful to also see nutrient and food data, adjusted for energy intake (e.g. intakes per 1000 kJ). This would provide a better understanding of differences in indicators diet quality between the two
2. Tables (including supplementary tables). Please ensure that there is consistency in the way that results are presented and the all necessary information about the analysis is provided in the footnotes. Some inconsistencies are noted below

- Supplementary table 2 indicates the reference group, using ref. but other tables do not.
- Suppl. Table 2: Please present the number of participants by country.
- Table 4 and Suppl. Table 3: Energy intake and physical activity variables have only one line of data and there are no odds ratios provided for the comparison groups. Please address this.
- Supplementary tables also indicate in the footnote that significant results are highlighted in bold (however not all statistically significant results are highlighted). A different approach is used for tables in the main manuscript.
- Please indicate the statistical tests used and how breakfast skipping was defined (e.g. based on questionnaire or 24-h recall) in the footnotes of each table
- Where sample size is further diminished due to participants missing information on covariates, please highlight this for the reader via another footnote.

3. Supplementary table 1 presents meal specific information (determined from the 24-h recall data) by breakfast skipping. However, not all participants consumed breakfast and I assume that not all participants would have two snacks per day. Please show the number of participants (for non-skippers & skippers) used for each meal analysis in additional table columns.

**Minor comments**

**Introduction**

Please provide references to support the following statement: “Furthermore, existing studies do not often adjust for many potential predictors of obesity, including…”

**Methods**

**Sociodemographic variables**

Please justify the cut-off of 15 y to dichotomize age.

**Diet and physical activity**

1. While the DQI has been explained in detail elsewhere, please give a brief description of the scoring system and components that relate to quality, diversity and equilibrium.

2. Please provide some examples of “savoury snacks”

**Statistical analysis**

Crude intakes, instead of mean intakes, were calculated for specific food groups due to their skewed distribution. I am not sure what is meant by crude intakes here. I would assume that medians (IQR) would be reported for this data?

**Results**

“Median (IQR) DQI was significantly higher among skippers than non-skippers;…”. It states in the method
that higher scores indicate better diet quality and this statement is not consistent with the conclusions drawn from the study. Please check and amend accordingly. If is also difficult to understand DQI results without knowing the score ranges for the quintiles. Please provide these in the tables.

**Is the work clearly and accurately presented and does it cite the current literature?**
Partly

**Is the study design appropriate and is the work technically sound?**
Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**
Partly

**If applicable, is the statistical analysis and its interpretation appropriate?**
Yes

**Are all the source data underlying the results available to ensure full reproducibility?**
Yes

**Are the conclusions drawn adequately supported by the results?**
Yes

**Competing Interests:** No competing interests were disclosed.

**Referee Expertise:** Nutritional epidemiology, eating (meal) patterns and obesity

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.