Is Obesity at Individual and National Level Associated With Lower Age at Menarche? Evidence From 34 Countries in the Health Behaviour in School-aged Children Study

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A unique standardized international data set from adolescent girls in 34 countries in Europe and North America participating in the Health Behaviour in School-aged Children Study (HBSC) is used to investigate the contribution of body mass index (BMI) at individual and country level to cross-national differences in age at menarche.

Methods: Two independent nationally representative survey data sets from 15-year-olds (n = 27,878, in 34 countries, year = 2005/2006) and 11-year-olds (n = 18,101, in 29 countries, year = 2001/2002) were analyzed. The survey instrument is a self-report questionnaire. Median age at menarche and 95% confidence intervals (CIs) were estimated using Kaplan–Meier analysis. Hierarchical models were used to assess the relationship between BMI and age at menarche (months). “Country-level obesity” was measured by prevalence of overweight/obesity (%) in each country.

Results: Country-level median age at menarche ranged between 12 years and 5 months and 13 years and 5 months. Country-level prevalence of overweight among 15-year-old girls ranged from 4% to 28%. Age at menarche was inversely associated with individual BMI (unstandardized regression coefficient beta = 1.01; 95% CI, 1.09 to 1.19) and country-level aggregate overweight at age 11 (unstandardized regression coefficient beta = 1.00; 95% CI, 0.93 to 1.08). Individual- and country-level measures of BMI account for 40% of the country-level variance in age at menarche.

Conclusions: The findings add to the evidence that obesity in childhood is a risk factor for early puberty in girls and accounts for much of the cross-national variation in age at menarche. Future HBSC surveys can track this relationship in the wake of the obesity “epidemic.”

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Increasing rates of childhood obesity over recent decades have been reported in many industrialized countries [1–3], and a range of associated health risks has been identified [4,5]. Among them is earlier puberty in girls that itself has major public health implications [6–8]. During adolescence, these include early initiation of sexual behavior [9] and substance use [10], body dissatisfaction and eating disorders [11], and depression [9]. Early puberty has also been identified as posing various health
Menarche is a relatively late marker of puberty and is a well-validated indicator of pubertal timing [12]. Age at menarche appears to have been declining in recent decades in western industrialized countries [13–15]. However, due to different study designs, there is a lack of standardized cross-nationally comparable data to accurately measure any decline [15].

Among the various social, economic, biological, and environmental factors implicated in the secular decline in age at menarche, there is growing evidence that rising levels of childhood obesity are of critical importance [8,16–18]. The decrease in average age at menarche during the past 40 years in the United States has been concurrent with an upward shift in the population distribution of body mass index (BMI) [19,20]. Several epidemiological reports in the past 30 years indicate a relationship between earlier menarche in girls and increased BMI [21]. Recent longitudinal studies suggest that increased body fat at birth or in early childhood, or rapid increase in BMI during infancy, predicts earlier onset of puberty [22–24]. However, there is a lack of standardized comparable data to evaluate the role of overweight (or BMI) in affecting age at menarche across different countries.

This article investigates the role of BMI in cross-national differences in age at menarche using a unique cross-nationally comparable data set generated by the 2005/2006 survey of the Health Behaviour in School-aged Children: World Health Organization Collaborative Cross-National Study (HBSC) [25]. For the first time, this allows the question of the relationship between obesity and age at menarche to be studied using standardized data from many countries, without problems of interpretation that arise from different methodologies and different cohorts.

**Methods**

The data are from the HBSC Study: a World Health Organization Collaborative Cross-National Study initiated in 1983, which currently includes 43 member countries in the European region, Canada, and the United States. Surveys are conducted every 4 years within the same period in all countries. A standardized international research protocol providing a conceptual framework and procedures for data collection and analysis is developed by study members [25]. The survey instrument is an internationally standardized self-report questionnaire, which is administered in the school classroom. The target population is schoolchildren in three age-groups, with desired means of 11.5, 13.5, and 15.5 years (hereafter called 11-, 13-, and 15-year-olds). Cluster sampling is used, with the class as the primary sampling unit, and a recommended sample size of approximately 1,500 for each age-group. The study complies with ethical standards in each country and follows ethical guidelines for research and data protection from the World Health Organization and the Organization for Economic Co-operation and Development. In the 2005/2006 survey, school/class- and pupil-level response rates exceeded 70% in most countries [25].

For this article, cross-sectional, internationally comparable data on age at menarche and BMI were collected from nationally representative random samples of 15-year-old girls (n = 27,878) from 3,066 schools in 34 countries that participated in the 2005/2006 HBSC survey. Sample sizes ranged from 170 in Malta to 1,281 in Germany. Further, aggregated country-level data on BMI among 11-year-olds (n = 18,101) were used from 29 of these countries that also participated in the 2001/2002 HBSC international survey.

**Measures**

**Menarcheal status and age at menarche.** Menarcheal status and age at menarche were determined from a two-part question in the international questionnaire asking, “Have you begun to menstruate (have periods?)” and requesting the age in year and months of first menstruation. Each girl was categorized as pre- or postmenarcheal. Girls who gave no information on month at menarche or whose reported age at menarche was either above their currently stated age, or below the age of 5 years, were excluded from the analysis. In total, 7,468 pupils (27%) were excluded from the analyses; most of these were excluded due to missing month in reported age at menarche.

**Body mass index (kg/m²).** BMI was calculated from self-reported height and weight, without clothes or shoes. Pupils were categorized as overweight or obese (hereafter referred to as “overweight”) using the International Obesity Task Force age- and sex-specific cutoffs [26]. Among 15-year-old girls in 2005/2006, 11% were missing data for BMI. Less than 5% of girls were missing both complete menarche data and BMI, and, of those who had complete menarche data, 7% (1,815) had missing BMI data.

Aggregated country-level prevalence of overweight was calculated for 15-year-olds in the 2005/2006 survey and 11-year-olds in the 2001/2002 survey. This latter group provides an independent country-level measure of overweight and, importantly, is based on a predominantly premenarcheal sample (86% premenarcheal) drawn from the same population cohort subsequently sampled in 2005/2006 when aged 15 years.

**Socioeconomic position.** Socioeconomic position was measured using the HBSC Family Affluence Scale (FAS) [27], a comprehensively validated summary index based on number of family holidays and cars, own bedroom, and computer ownership, with summary scores ranging from 0 (lowest affluence) to 7 (highest affluence). The measure is split into approximate tertiles of family affluence across all countries [28]. Less than 1% of girls (204) with complete data for age at menarche and BMI were missing data for FAS.

**Statistical analyses**

Median age at menarche in each country and associated 95% confidence intervals (95% CIs) were calculated using Kaplan-Meier analysis. Univariate age- and FAS-adjusted regression was used to measure the association between individual BMI and age at menarche (dependent variable) among 15-year-olds in 2005/2006. Univariate regression was also used to carry out ecological analyses measuring the relationship between country-level median age at menarche (dependent variable) and aggregated country-level prevalence of overweight based on data from 15-year-olds (in 2005/2006) and from data from 11-year-olds (in 2001/2002). Subsequent analyses used hierarchical models to simultaneously assess the relationship between BMI and age at menarche at individual and at country level. The country-level indicator of obesity is measured by the aggregate prevalence of overweight among 11-year-olds from 2001/2002 survey data. The use of this predominantly premenarcheal group clarifies the interpretation of any association found between BMI and men-
analyses by implying direction of relationship (i.e., BMI in childhood influencing age at menarche).

To permit comparison of hierarchical models, analyses were restricted to the 29 countries, which had BMI data from both survey sweeps, and to girls for whom complete data were available for age at menarche BMI, and FAS in the 2005/2006 data set (N = 15,783). Four-level hierarchical models were constructed, adjusted for age and FAS. These levels were individual, school, sampling strata (e.g., geo-political units or language groups), and country.

Model 1 included only the structural covariates, current age, and family affluence. This model will indicate whether there is significant variation between countries in age at menarche, after adjusting for family affluence and current age. Model 2 also included individual BMI to assess the extent to which variation in BMI between individuals reduced the residual country-level variation. Model 3 additionally included aggregate prevalence of overweight among 11-year-olds in 2001/2002 to assess whether this independent country-level measure of BMI was associated with age at menarche (independent of individual-level BMI), and whether addition of this country-level measure of overweight reduced residual country-level variance further. To assess the change in country-level variance between models, the country-level intraclass correlation (ICC) was used. The country-level ICC measures the proportion of the variance in age at menarche that is attributable to country-level variation. The ICC from models 2 and 3 are expressed as a percentage of the ICC from model 1 to show the change in country-level residual variance, as individual- and subsequently country-level BMIs are included in the models. Current age, individual BMI, and age at menarche were centered for regression analyses, and age at menarche was imputed as current age for those who were premenarcheal. All analyses were carried out using Stata 10.1 (StataCorp LP, College Station, TX).

Results

Mean current age among 15-year-olds in the 2005/2006 survey was 15.6 years (standard deviation [SD] = .37) and among 11-year-olds in the 2001/2002 survey was 11.6 years (SD = .41). Among 15-year-old girls (2005/2006 survey) with complete menarche data, 2.7% were premenarcheal, and mean FAS score was 4.6 (SD = 1.67).

Cross-national variation in BMI and age at menarche

Based on reports of 15-year-olds in the 2005/2006 survey, there was a substantial variation among individuals and across countries in age at menarche (Table 1). In 95% of individuals, age at menarche ranged between 10 years 6 months and 14 years 11 months. Less than 1% were younger than 10 years 0 months. Country-level median age at menarche ranged from 12 years and 5 months in Italy to 13 years and 5 months in Latvia.

Aggregate country-level prevalence of overweight varied substantially across countries: from 4% (Romania) to 28% (Malta) among 15-year-olds in 2005/2006, and from 4% (Estonia) to 21% (United States) among 11-year-olds in 2001/2002 survey (Table 1).

Association between BMI and age at menarche: individual-level analyses

Regression analysis using 2005/2006 data from 15-year-olds in 34 countries shows a significant negative association between individual BMI and age at menarche (Table 2). For each unit increase in BMI, age at menarche is earlier by about 1 month (unstandardized regression coefficient $\beta = -1.05$; 95% CI, $-1.12$ to $-0.98$). Repeating this analysis for each country separately, age at menarche was earlier in girls with higher BMI in all countries (unstandardized beta coefficients ranged from $-1.59$ to $-0.60$); however, in two countries, namely, Malta ($\beta = -0.66$) and Portugal ($\beta = -0.48$), this relationship was not statistically significant.

Association between BMI and age at menarche: ecological analyses

Treating countries as units, that is, applying ecological analyses, a strong negative association was noted between aggregate prevalence of overweight and median age at menarche among 15-year-olds in 2005/2006 (Table 3). For each percentage increase in country-level prevalence of overweight, median age at menarche was approximately 1 week earlier (unstandardized regression coefficient $\beta = -0.24$; 95% CI, $-0.39$ to $-0.05$). As the country-level prevalence of overweight ranged between 4% and 28%, this could equate to a difference in age at menarche of as much as 24 weeks (approximately 6 months). When the analysis was repeated using country-level data on overweight from 11-year-olds in 2001/2002, the direction and strength of this relationship was similar ($\beta = -0.33$; 95% CI, $-0.52$ to $-0.14$).

Association between BMI and age at menarche: multilevel analyses

Multilevel regression models were used to measure the association between BMI and age at menarche, and to assess the extent to which country-level variation in age at menarche could be explained by individual- and country-level BMI. The age- and FAS-adjusted model indicates there is substantial variation in age at menarche between countries, with a small but significant proportion of the unexplained variance (ICC = 3.1%) at country level (Table 4: model 1). The highest residual variance in age at menarche is at the individual level, as would be predicted. The second model includes individual BMI. Country-level variance in age at menarche decreases the ICC by 20%, and for each unit increase in BMI, age at menarche is approximately 1 month earlier (Table 4: model 2). The third model, adding in country-level prevalence of overweight among 11-year-olds in 2001/2002, does not change the fixed-effect estimates (regression coefficients) but accounts for a further 20% of country-level variance in age at menarche (Table 4: model 3). In this final model, for each unit increase in BMI at individual level, age at menarche is 1 month earlier (unstandardized regression coefficient $\beta = -1.01$; 95% CI, $-1.09$ to $-0.94$), and for each percentage point increase in prevalence of overweight/obesity at country level, age at menarche is approximately 1 week earlier (unstandardized regression coefficient $\beta = -0.25$; 95% CI, $-0.43$ to $-0.08$). There remains substantial variance at all levels not accounted for by BMI.

Discussion

There is growing evidence that childhood obesity is an important determinant of early menarche [16–18]. This article contributes to the evidence base by examining associations between adolescent obesity and age at menarche across countries in Europe and North America. The data were collected using standardized methodology and validated measures [25].
whereas few harmonized cross-national data have been previously available [15].

Median age at menarche differed by as much as a year between countries in Europe and North America. This is similar to the difference in age at menarche between two U.S. cohorts, 60 years apart (in the 1920s and 1980s), reported by McDowell et al [29]. Along with the evidence that age at menarche has decreased in recent decades in many industrialized countries [12–15] is the observation that the rate of decline varies between countries, and this may be linked to changing prevalence of obesity [18]. Anderson et al [19] suggest these are corresponding processes in their analysis of changes in age at menarche and prevalence of obesity in the United States. The findings in this article contribute to the debate around such a hypothesis.

There is a sevenfold difference in prevalence of overweight among 15-year-old girls in the 34 countries surveyed in 2005/2006, which is a finding similar to comparable data from the 2001/2002 HBSC survey [30]. Highest rates are found in the United States and western and southern Europe, and lowest rates are found among countries in Eastern Europe, these differences in prevalence being associated with levels of country wealth [30]. Haug et al [3] report that two-thirds of countries participating in both the 2001/2002 and 2005/2006 surveys show an increase in overweight prevalence between survey sweeps, but that the “obesity epidemic” is at different stages of progression from west to east.

The inverse associations between BMI and age at menarche found at individual and country levels and between cohorts are in line with longitudinal research, which indicates that childhood BMI influences timing of puberty with overweight predicting earlier onset and staging of different markers [8,17,22–24].

### Table 1
Summary by country of median age at menarche (and 95% confidence interval and sample size), and percentage overweight/obese at age 15 and at age 11. HBSC study, 2005/2006 and 2001/2002

| Country/region | 15-year-old girls (2005/2006) | 11-year-old girls (2001/2002) |
|----------------|-------------------------------|-------------------------------|
|                | Median age at menarche (N)    | Percentage overweight/obese | Percentage overweight/obese |
|                | Months (years and months)     | 95% CI (months)               |
| Italy          | 580                           | 149 (12 years 5 months)       | 147.7–150.3                  | 9.6           | 13.4 |
| Portugal       | 459                           | 152 (12 years 8 months)       | 149.9–154.1                  | 13.6          | 20.7 |
| Canada         | 696                           | 153 (12 years 9 months)       | 151.6–154.4                  | 15.6          | 14.4 |
| Greenland      | 165                           | 153 (12 years 9 months)       | 151.0–155.0                  | 22.4          | 16.0 |
| Austria        | 607                           | 154 (12 years 10 months)      | 152.3–155.7                  | 9.3           | 11.8 |
| Malta          | 167                           | 154 (12 years 10 months)      | 150.4–157.6                  | 28.2          | No data |
| Netherlands    | 532                           | 154 (12 years 10 months)      | 152.4–155.6                  | 10.1          | 7.5  |
| Estonia        | 611                           | 154 (12 years 10 months)      | 152.8–155.2                  | 10.6          | 16.8 |
| United States  | 457                           | 154 (12 years 10 months)      | 151.8–156.2                  | 23.7          | 21.1 |
| England        | 444                           | 156 (13 years 0 months)       | 153.9–158.1                  | 8.2           | 21.1 |
| Finland        | 670                           | 156 (13 years 0 months)       | 154.7–157.3                  | 11.6          | 12.3 |
| France         | 1,067                         | 156 (13 years 0 months)       | 153.5–156.7                  | 8.0           | 9.3  |
| Ireland        | 596                           | 156 (13 years 0 months)       | 154.7–157.3                  | 9.3           | 7.7  |
| Norway         | 665                           | 156 (13 years 0 months)       | 155.3–156.7                  | 8.4           | 10.0 |
| Bulgaria       | 637                           | 157 (13 years 1 month)        | 155.6–158.4                  | 6.0           | No data |
| Switzerland    | 534                           | 157 (13 years 1 month)        | 155.5–158.5                  | 7.5           | 8.5  |
| Germany        | 749                           | 157 (13 years 1 month)        | 155.6–158.4                  | 11.3          | 8.7  |
| Denmark        | 485                           | 157 (13 years 1 month)        | 155.5–158.5                  | 9.0           | 10.0 |
| Greece         | 657                           | 157 (13 years 1 month)        | 155.4–158.6                  | 11.1          | 11.8 |
| Sweden         | 593                           | 157 (13 years 1 month)        | 155.6–158.4                  | 9.6           | 8.3  |
| Ukraine        | 941                           | 157 (13 years 1 month)        | 156.3–157.7                  | 4.7           | 6.4  |
| Wales          | 489                           | 157 (13 years 1 month)        | 155.4–158.6                  | 19.3          | 17.0 |
| Croatia        | 734                           | 158 (13 years 2 months)       | 157.1–158.9                  | 10.3          | 9.8  |
| Hungary        | 411                           | 158 (13 years 2 months)       | 156.3–159.7                  | 11.4          | 10.2 |
| Iceland        | 749                           | 158 (13 years 2 months)       | 156.4–159.6                  | 11.4          | No data |
| Slovenia       | 578                           | 158 (13 years 2 months)       | 156.6–159.4                  | 10.2          | 11.8 |
| Slovakia       | 405                           | 158 (13 years 2 months)       | 156.8–159.2                  | 4.3           | No data |
| Belgium (Flemish) | 631                         | 159 (13 years 3 months)       | 157.8–160.2                  | 6.4           | 8.6  |
| Poland         | 803                           | 159 (13 years 3 months)       | 158.1–159.9                  | 6.3           | 6.5  |
| Romania        | 837                           | 159 (13 years 3 months)       | 158.1–159.9                  | 4.2           | No data |
| Estonia        | 576                           | 160 (13 years 4 months)       | 158.9–161.1                  | 5.4           | 4.3  |
| Israel         | 633                           | 160 (13 years 4 months)       | 158.8–161.2                  | 8.5           | 7.5  |
| Macedonia      | 853                           | 160 (13 years 4 months)       | 159.1–160.9                  | 6.3           | 13.4 |
| Latvia         | 399                           | 161 (13 years 5 months)       | 159.8–162.2                  | 6.2           | 5.3  |
| All regions    | 20,410                        | 157 (13 years 1 months)       | 156.8–157.2                  | 9.5           | 10.8 |

*Note:* Total sample size 18,595.

### Table 2
Linear regression analysis for age at menarche (months) among 15-year-olds

| Independent variables | Unstandardized regression coefficient | 95% CI |
|-----------------------|---------------------------------------|-------|
| Body mass index (BMI) | −1.05                                 | −1.12 to −.98 |
| Current age (months)  | .13                                   | .08 to .17 |
| Family affluence score| .06                                   | −.17 to .29 |
| Constant              | .30                                   | −.18 to −.78 |

N = 18,391. p < .001. Age at menarche and current age are measured in months. Age at menarche, BMI, and current age are centered. CI = confidence interval. Data source: HBSC 2005/2006 survey.
A cause of later obesity rather than an outcome of early childhood pathway described, other research indicates that early puberty is directly affects gonadotropin secretion to influence the timing of their weight in self-reports [12,35,36]. Such an underestimation young women in the United States and Europe to underestimate missing menarche data. There is a tendency among girls and is no evidence of reporting bias with respect to BMI in those infant feeding [1,34].

In the hierarchical models, premenarcheal girls were included by imputing age at menarche as their current age. Few cases were imputed (<3% of 15-year-old girls were premenarcheal), and this was considered a relatively conservative approach, that is, less likely to artificially strengthen the relationship posited between increasing BMI and decreasing age at menarche, while including the maximum number of girls for whom menarcheal status was available.

Table 3
Linear regression analysis for country-level median age at menarche among 15-year-olds in 2005/2006

| Model | Unstandardized regression coefficients | 95% CI |
|-------|----------------------------------------|--------|
| 1. 15-year-old girls 2005/2006 | Country-level prevalence of overweight (%) | -0.24 | -0.39 to -0.05 |
| | Constant | 159.01 | 157.29 to 160.73 |
| 2. 11-year-old girls 2001/2002 | Country-level prevalence of overweight (%) | -0.33 | -0.52 to -0.14 |
| | Constant | 160.11 | 157.73 to 162.49 |

Country-level median age at menarche is measured in months; country-level prevalence of overweight is measured in percent.

Model 1: Independent variable: prevalence of overweight among 15-year-olds (2005/2006), N = 34 countries, p = .002.
Model 2: Independent variable: prevalence of overweight among 11-year-olds (2001/2002), N = 29 countries, p = .001.
CI = confidence interval.
Data source: HBSC 2005/2006, HBSC 2001/2002.

24,31]. Kaplowitz [21] argues that leptin produced by fat cells directly affects gonadotropin secretion to influence the timing of puberty. Although our article presents good evidence for the pathway described, other research indicates that early puberty is a cause of later obesity rather than an outcome of early childhood obesity [32]. It has also been argued that common genes explain the association between overweight and early menarche [33]. Our research cannot rule out this latter explanation, and further research is required among the adolescent population to ascertain the relative contribution of genetic and environmental factors.

Our study indicates that individual- and country-level BMI contribute to variation in age at menarche seen between countries. The fact that country-level BMI remained associated with age at menarche independently of individual-level BMI suggests that country-level measures of BMI may be proxy indicators of obesogenic factors, such as food availability and price, opportunities for physical activity, maternal health and nutrition, and infant feeding [1,34].

Although little data were missing for FAS, missing data on menarche and BMI were high in some countries. However, there is no evidence of reporting bias with respect to BMI in those missing menarche data. There is a tendency among girls and young women in the United States and Europe to underestimate their weight in self-reports [12,35,36]. Such an underestimation could mean the strength of the relationship between BMI and age at menarche is slightly weaker than reported. In particular, if underestimation of BMI is greater among the most overweight girls, then the relationship between BMI and age at menarche could be attenuated at higher BMI, with the relationship perhaps being curvilinear. Other studies have reported high accuracy for classification of youth as obese or nonobese based on self-reported data, and that BMI based on self-reports is fairly reliable [37] and suitable for identifying valid relationships in epidemiological studies [38].

The possibility that underreporting of BMI co-occurs with overreporting of age at menarche could be another concern. However, although underreporting of BMI is likely to be related to sensitivity about weight [39], no such bias has been recorded in reported timing of menarche. Indeed, recalled and actual ages at menarche are reported to be highly correlated, especially when recall is close to the age of menarche [40].

In the hierarchical models, premenarcheal girls were included by imputing age at menarche as their current age. Few cases were imputed (<3% of 15-year-old girls were premenarcheal), and this was considered a relatively conservative approach, that is, less likely to artificially strengthen the relationship posited between increasing BMI and decreasing age at menarche, while including the maximum number of girls for whom menarcheal status was available.

Table 4
Summary of results from multilevel models of age at menarche (months) among 15-year-olds across 29 countries

| Factors | Model 1 adjusted for structural covariates | Model 2 addition of individual BMI | Model 3 addition of country-level overweight |
|---------|--------------------------------------------|-----------------------------------|--------------------------------------------|
| Fixed effects (95% CI) | | | |
| Individual level | | | |
| Family affluence | .75 (.48 to 1.02) | .53 (.26 to .80) | .54 (.27 to .81) |
| Current age (months) | .06 (.00 to .12) | .09 (.03 to .14) | .09 (.03 to .14) |
| Body mass index (BMI) | — | -1.02 (-1.09 to -.95) | -1.01 (-1.09 to -.94) |
| Country Level | | | |
| Prevalence of overweight (%) of 11-year-olds in 2001/2002 | — | — | -2.5 (-4.3 to -.08) |
| Random effects (SE) | | | |
| Country-level variance | 6.32 (2.05) | 4.83 (1.64) | 3.53 (1.28) |
| Country-level ICC as percentage of model 1 ICCa | 100% | 80% | 59% |
| Strata-level variance | 3.11 (.83) | 3.22 (.83) | 3.18 (.83) |
| School-level variance | 7.36 (1.12) | 6.84 (1.07) | 6.85 (1.07) |
| Residual (individual level) variance | 187.61 (2.26) | 179.07 (2.16) | 179.07 (2.16) |
| Log Likelihood | -64,049.85 | -63,676.79 | -63,673.25 |
| Likelihood-ratio test for change in log likelihood | p < .0001 | p < .01 |

Age at menarche is measured in self-report age in months, or current age for premenarcheal girls.
Model 1: Adjusted only for current age and family affluence.
Model 2: Adjusted for individual BMI measure in addition to current age and family affluence.
Model 3: Adjusted for country-level prevalence of overweight (%) among 11-year-olds in 2001/2002, in addition to individual-level BMI, current age, and family affluence.
CI = confidence interval.

a Country-level intraclass correlation coefficient measures the proportion of observed variation in age at menarche attributable to country level.

Data source: HBSC 2005/2006, HBSC 2001/2002.
Although there is a rather high level of missing BMI data in a small number of countries, we find a consistent relationship between BMI and age of menarche among 15-year-olds in all countries, regardless of the extent of missing BMI data. Although ideally an independent country-level measure of obesity in early childhood would have been preferable to the use of data from 11-year-olds for this study, the HBSC data used are cross-nationally comparable, contemporaneous, and largely represent a premenarcheal population group as required. In future, the HBSC study can simultaneously track BMI and age at menarche in Europe and North America, and so contribute to the evidence base around the relationship between obesity and puberty in girls. The continued monitoring of secular trends in puberty remains important to public health agendas due to both short- and long-term effects on psychological and physical health of early puberty [18]. The findings suggest an important association between overweight and age at menarche at individual and country level. Future studies could consider how overweight relates to other factors, such as diet, physical activity, social environment, and genetics, to explain, in particular, the country-level associations found here.

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