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A neglected determinant of eating behaviors: Relative age

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Abstract

This study investigates a neglected determinant of adolescents' dietary behaviors: the within-class age difference, in isolation from confounding factors (e.g., absolute age, season-of-birth, and countries' specific characteristics, such as expected age at school start). We study a multi-country dataset, with more than 500k students, from dozens of very diverse countries. We find that the youngest students in a class have worse dietary behaviors; they are more likely overweight, they eat fewer vegetables and fruits, they eat more sweets and drink more soft drinks, they tend to skip breakfast, go to bed hungry, and be on a diet. These findings are likely to reflect peer effects: two students with the same absolute age, who were born in the same season, and started school at the same time, have different dietary behaviors because of how their age compares to that of their classmates. Finally, we show that this result holds across countries, which demonstrate the ubiquity of relative age effects on eating behaviors.

Keywords: Diet, Adolescence, Causal, External validity, Relative age.
JEL Codes: I12, I18, I24.

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1 Introduction

The increased ubiquity of unbalanced diets is worsening the phenomenon called 'globesity.'[1] This trend is particularly worrisome among adolescents: their obesity prevalence has increased exponentially in the last 50 years, all over the world, to the point that the quantity of overweight adolescents exceeds that of underweight adolescents (Abarca-Gómez et al., 2017). The increased sedentary lifestyle due to the COVID-19 pandemic has further accelerated this phenomenon (Nour & Altintaş, 2023).

An unbalanced diet has repercussions beyond body-weight issues. The intake of fruits and vegetables is associated with lower depression rates and greater well-being (Akbaraly et al., 2009; Jacka et al., 2011; McMartin et al., 2013; Cobb-Clark et al., 2014; Mujcic & J. Oswald, 2016), as well as fewer physiological diseases, such as oropharynx, esophagus, lung, stomach, and colorectum cancer (Soerjomataram et al., 2010; Wallace et al., 2020). A nutritious diet also has positive benefits on cognitive abilities, with positive repercussions in terms of lifetime income (Au et al., 2016; Frisvold, 2015; Lundborg et al., 2022). Thus, the identification of the determinants of adolescents' dietary behaviors is a fundamental quest.

Some of the most influential determinants of adolescents' dietary behaviors are found in the school environment. A growing literature shows the pivotal role of school peers' dietary and weight management behaviors (Yakusheva et al., 2011; Fortin & Yazbeck, 2015; Gwozdz et al., 2019); this literature finds positive effects of peers' virtuous behaviors and detrimental effects of negative behaviors. A second strand of the literature shows that the school provision of nutritious meals positively affect students' dietary behaviors, leading to long-term benefits (Au et al., 2016; Frisvold, 2015; Lundborg et al., 2022). In this study, we investigate a neglected school determinant of adolescents' dietary behaviors: the within-class age difference (henceforth, relative age).

The literature shows that relative age has far reaching effects on individuals' well-being. There is evidence that relatively young students tend to be unsatisfied with life, and to have a worse mental and physical health than their older peers (Fumarco et al., 2020; Black et al., 2011), and are more likely to be (mis)diagnosed with attention deficit and hyperactivity disorder (Layton et al., 2018; Schwandt & Wuppermann, 2016; Furzer et al., 2022; Dee & Sievertsen, 2018; Elder & Lubotsky, 2009; Evans et al., 2010; Balestra et al., 2020).[2] These outcomes are associated with worse dietary behaviors (O'Neil et

[1] Term used by the WHO.

[2] There are additional effects beyond the scope of this study, such as on risky behaviors, unwanted

al., 2014). Various disciplines provide evidence that relatively young students do less sport activity as well (Smith et al., 2018; Dixon et al., 2020; Fumarco & Schultze, 2020), [3] Like only a few other topics, such as discrimination and gender gaps, relative age is a limitless topic of scientific scrutiny across social and health sciences (Dhuey & Koebel, 2022; Layton et al., 2018; Smith et al., 2018; Dixon et al., 2020).

The relative age phenomenon is far reaching in geographic terms as well. It is of the broadest interest because it stems from two omnipresent features of modern educational systems. First, a cutoff date for children's enrollment in school, which determines who is the oldest pupil in a cohort. Second, the 12-month grouping cohort; based on this rule, within the same cohort, students' age can differ by twelve months at most–net of retention and grade skipping, redshirting (i.e., entering school one year later) and greenshirting (i.e., entering school one year earlier), where they are possible. Potentially, a large share of people from all over the world may suffer from negative relative age effects: if we ideally split classes in two subgroups around the median age, *about 50% of students* may be suffering from this disadvantageous age-grouping system in education and in later stages.[4] Thus, this is a topic of great general interest as only a few others.

It should not come as a surprise that relative age has gathered momentum with the general public. It is discussed in popular science books (e.g., Gladwell's "Outliers" (Gladwell, 2008), Levitt and Dubner's "SuperFreakonomics" (Levitt & Dubner, 2011)), and newspapers (e.g., on The New York Times, The Guardian, and The Independent). It is debated among parents and by leading international organizations, such as the World Economic Forum.

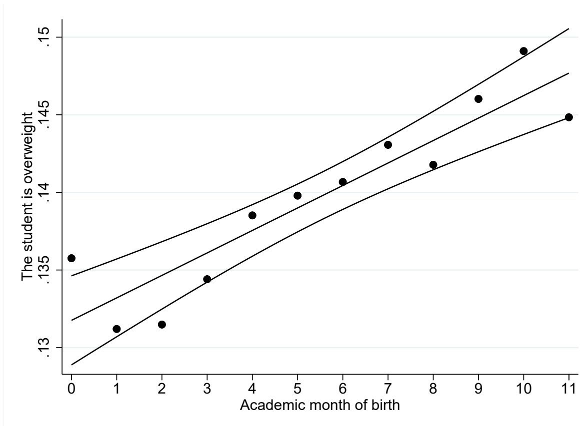
Our study provides highly internally and externally valid evidence of ubiquitous relative age effects on dietary behaviors. We study data from the 'Health Behaviour in School-Aged Children (HBSC)' survey and investigate relative age effects on objective and subjective overweight, on the probability of being on a diet, on the frequency of consuming soft-drinks, sweets, vegetables and fruits, and on the probability of going to bed hungry and having breakfast. With this dataset, we investigate a representative sample of European students, from 10 to 17 years of age, from 32 European countries,

births, sexually transmitted diseases (Johansen, 2021), juvenile crime (Landersø et al., 2017), and mothers' labour market outcomes (Landersø et al., 2020), to name just a few examples.

[3]Some literature provides evidence that relatively young students are more likely overweight (Fumarco et al., 2020; Anderson et al., 2011), but they do not look into general dietary behaviors.

[4]This is a solomonic fashion to split students based on their relative age. In reality, one should think of relative age as being a continuous treatment, which becomes stronger the wider becomes the age difference of student i with respect to the reference student (e.g., the oldest student in class or the hypothetical average age in class).

Figure 1: Mean values of objective overweight status per academic month of birth.



Note: Student i's probability of being overweight on the y-axis, and academic month of birth on the x-axis. The latter represents the expected relative age, that is, the expected age difference of student i with respect to the hypothetically oldest student in class, who is born in the month that starts with the cutoff date that determines school cohorts. Academic month of birth 0 is the month that starts with the cutoff. The graph reports 90% confidence intervals and is based on regular students (i.e., students who have not been redshirted, greenshirted, retained, or skipped the grade).

which highly differ from each other in terms of characteristics of the education system and diet health-parameters.

Basic descriptive statistics visibly confirms our expectations on the relationship between students' relative age and dietary behaviors. Figure 1 shows a positive correlation between a proxy for relative age and students' probability of being objectively overweight. Similar descriptive figures are available in the replication package for the other outcomes we study.

This descriptive evidence is confirmed by regression analyses. We use a two-stage least square to account for the endogeneity of relative age. Relatively young students are more likely objectively and subjectively overweight; moreover, they are more likely on a diet. Furthermore, we find that relatively young students consume more candies and soft drinks, and less fruit and vegetables. Finally, they are more likely to go to bed hungry and skip breakfast on weekdays, but not on weekends. While we cannot pin point the mechanisms that lead to these results, we should stress that they are net of absolute age effects,[5] and other confounders, such as season-of-birth effects. Therefore,

[5]There are four most important age effects investigated in the literature. Relative-age effect, that is, the effect of age differences between classmates. Age-at-school start effect, that is, the effect of the age at which students start school. Age-at-outcome effect, that is, the effect of the age at which the outcome was measured (or the survey was conducted). Time-in-school effect, that is, the effect of the time spent in school. All these different but related age effects cannot be typically disentangled.

these findings are likely to reflect peer effects: two students with the same absolute age, who were born in the same season, and started school at the same time, have different dietary behaviors because of how their age compares to that of their classmates.

Previous literature suggests that a few aspects might play a pivotal role. With this respect, we investigate the role of country-wise diet. First, analyses at country-level show that the main results are incredibly consistent, like only a few other social phenomena. Second, we observe that the results do not tend to vary based on how healthy the general health level of the country diet.

Section 2 illustrates data and variables. Section 3 describes methods and results. Section 4 discusses and concludes.

2 Data and Variables

This analysis draws from survey data from the 'Health Behaviour in School-Aged Children (HBSC),' all the five publicly available waves: 2001/2, 2005/6, 2009/10, 2013/14, and 2017/18. To this data, we added information on countries' Alternative Healthy Eating Index. The following subsections discuss data and methods.

Data

The HBSC is a multi-country survey that focuses on adolescents' health and well-being, and is administered in schools every four years. From five waves, we exclude observations from countries for which we could not retrieve information on the cutoff date, for which the cutoff does not fall on the first day of the month,[6] and countries that adopt multiple cutoffs–because we do not have information on the school's region or state. The final sample is composed of more than 600,000 students from 32 highly diverse countries.[7] The primary sampling unit is the class. Table A.1 in the Appendix includes the number of observations per country per wave, while Table A.2 reports the

Due to the features of the dataset at hand, we are able to isolate relative age from the other three factors. While age at school start–which is given by country-wise regulations, is captured by country fixed-effects, we are still not able to disaggregate age-at-outcome from time-in-school.

[6] HBSC data do not include information on the day of birth, so it is not possible to tell whether a student is born before of after the cutoff date, when this falls in the middle of the month. In countries where the cutoff is the first day of the month, we know that who is born whenever in that month is born after the cutoff date.

[7] More correctly, it is 30 countries. In two countries, the HBSC survey is independently conducted in different regions: in Belgium there are two surveys for the Flanders and Wallonia, whereas in Denmark there are two surveys for the mainland and for Greenland.

country-specific cutoff date. AHEI stands for Alternative Healthy Eating Index, which is discussed in Miller et al. (2022) [8]; this is a validated score of diet quality at the country level.

Outcome variables

We investigate ten outcome variables. *(i)* Objective overweight, a dummy variable which equals one if the student is overweight (the underlying information was not collected in wave 2006). This variable is based on a standardized anthropometric measure (i.e., body mass index measured as kg/m^2) that accounts for students' age and gender (Vidmar et al., 2013). *(ii)* Subjective overweight, a dummy variable which equals one if the student thinks to be at least a bit too fat. *(iii)* On a diet, a dummy variable which equals one if the student is on a diet or is doing something else *(iv)* Vegetables, a dummy variable which equals one if the student consumes vegetables at least 5 days a week. *(v)* Fruits, a dummy variable which equals one if the student consumes fruits at least 5 days a week. *(vi)* Sweets, a dummy variable which equals one if the student consumes sweets at least 5 days a week. *(vii)* Soft drinks, a dummy variable which equals one if the student consumes soft drinks at least 5 days a week. *(iix)* Hungry to bed, a dummy variable which equals one if the student goes to bed hungry at least sometimes (the underlying survey question was asked neither for wave 2014 nor 2018). *(ix)* Breakfast on schooldays, a dummy variable which equals one if the student gets breakfast on all five schooldays. *(x)* Breakfast on weekends, a dummy variable which equals one if the student gets breakfast on both weekend days. [9]

Table 1 reports number of observations, means, standard deviations, min and max values for the outcomes, relative age, the instruments, and other independent variables.

[8] Country level scores are accessible from the authors' website.

[9] Similar questions on dinner and lunch were asked only for 2001; thus, due to lower comparability and lack of statistical power, we have excluded analyses on these outcomes.

Table 1: Descriptive statistics.

Variable	Obs.	Mean	SD	Min	Max
Objective overweight	402,628	0.139	0.346	0	1
Subjective overweight	616,973	0.319	0.466	0	1
On a diet	489,984	0.441	0.496	0	1
Vegetables	611,230	0.525	0.499	0	1
Fruits	612,554	0.387	0.487	0	1
Sweets	611,326	0.385	0.487	0	1
Soft drinks	611,637	0.298	0.457	0	1
Hungry to bed	362,465	0.170	0.376	0	1
Breakfast school	585,129	0.636	0.481	0	1
Breakfast weekend	591,378	0.934	0.247	0	1
RA	597,327	-0.306	0.454	-5.750	5.167
AA	616,973	0	1.646	-3.703	3.463
Female	616,973	0.508	0.500	0	1
Parents	596,387	0.760	0.427	0	1
SES: Low	616,973	0.367	0.482	0	1
SES: Medium	616,973	0.229	0.420	0	1
SES: High	616,973	0.403	0.490	0	1
ERA	616,973	5.529	3.373	0	11
EAA	616,973	13.521	1.635	10.25	17

Note: RA is relative age, AA is absolute age and it is centered around the mean. ERA and EAA are expected relative and absolute age. SES stands for socio-economic status. Analyses additionally include vectors for wave, country, and season of birth fixed-effects.

Relative age

Relative age, RA_{ic}, is measured as the difference between student i's age in class c, AGE_{ic}, and the age of the oldest regular student I in class c, AGE_{Ic}, as in Equation [1].

$$RA_{ic} = AGE_{ic} - max(AGE_{Ic}|I \in R_c) \tag{1}$$

Thus, an increase in relative age means that student i is relatively older. A regular student is a student enrolled in the right class based on her age and on the country cutoff date.

This measure usually ranges between 0–for the oldest regular student i in class c– and -1–for the youngest regular student i in the same class c. Due to non-random grade skipping, greenshirting, retention, and redshirting, relative age is endogenous and goes beyond this range for non regular students.[10] Thus, this variable is instrumented with expected relative age, see below.[11]

There is one additional remark. On one hand, relative age variation at class level improves the estimate of peer effects; on the other hand, it does not allow us to control for class fixed-effects. However, we conducted additional analyses with fixed-effects at school level, instead of country and wave,[12] and the results are similar.

Expected relative age

The instrument for relative age is expected relative age ERA_{iCOU}, that is, the month of birth of student i within the academic year (henceforth, academic month of birth) of country COU. Academic month of birth is a proxy for the relative age that student i would have had, had she been a regular student. This variable ranges between 0 and 11. Zero is the reference month, corresponding to the hypothetically oldest student in a class, while eleven corresponds to the academic month of the hypothetically youngest student in a class.

We disaggregate this variable into individual month dummies–similar to what is suggested in Angrist and Pischke (Angrist & Pischke, 2008), so that the instrument of observed relative age is actually a vector of dummies. This disaggregation allows us to improve the fit of the first stage and to conduct the overidentification test.

[10]Relative age could be endogenous due to cesarean section around the cutoff date as well, although there is little evidence of this phenomenon (Dickert-Conlin & Elder, 2010). It determines one student to start school earlier and to be relatively younger, instead of relatively older, had she been born right after the cutoff date. In terms of occurrences, this is a marginal cause of endogeneity, but it is possible and it is taken care of by the two-stage least square.

[11]There could be one alternative way to measure relative age: the distance of student's i age from the average age in class. The replication package includes analyses with this alternative variable specification and the obtained results are equivalent. Some literature studies the effect of class-specific performance rank on educational outcomes, so one may wonder whether we could similarly use a class-specific age rank; however, this measure would neglect the importance of actual age differences. Being ranked 10th in the class-specific age rank with only a three-month difference from the oldest student in a class is not the same as being ranked 10th and facing a ten-month difference.

[12]This is because there are different schools in each wave.

Tabel A.3 in the Appendix reports results on joint orthogonality tests on the instruments. The results are reassuring because it does not look like expected relative age is affected by observable characteristics; these results are described in more details below.

Table A.4 in the Appendix reports first-stage results. This table shows that academic months of birth (i.e., the exogenous instrument that represents a proxy for expected relative age) have a negative and increasing effect on observed relative age (i.e., the endogenous independent variable of interest); in other words, later academic months of birth are associated with lower relative age.

Control variables

Absolute age at survey participation could also be endogenous, for similar reasons as relative age is.[13] The instrument for absolute age is expected absolute age, EAA_i, that is, the absolute age that student i would have if she was a regular student. It is computed as the expected absolute age of students who are surveyed in the same wave and in the same country, attend the same classroom, and were born in the same quarter, similar to Peña and Duckworth (Peña & Duckworth, 2018).

To account for general differences in adolescents' food preferences and body weight regulation across genders, we control for students' gender (Caine-Bish & Scheule, 2009; Cooke & Wardle, 2005; Rolls et al., 1991). This variable equals one for female students and zero for male students, the reference group. Since previous studies indicate that having divorced or separated parents can affect students' weight control and dietary behaviors, we control for whether the student lives with both parents (Elfhag & Rasmussen, 2008; Shisslak et al., 1998). Landersø et al. (Landersø et al., 2020) find that relative age affects marriage stability in Denmark, which suggests that this variable might be a bad control. However, results from the balance tests in Table A.3 in the Appendix do not show any relationship between relative age and family status. This is probably because we use data from all over Europe, which allows us to account for country specific characteristics. Local circumstances, such as gender norms, availability of kindergartens, features of the educational system, might play a role in individual countries. As an additional robustness checks, we exclude this control variable but the main results are unchanged; these analyses are available in the replication package.

To account for the positive association between parental socio-economic status and children's dietary habits, we add family socio-economic status (SES) as an additional

[13] For example, due to the manipulation of birth date with a cesarean section.

control variable (Ahmadi et al., 2015; "Socio-economic and cultural disparities in diet among adolescents and young adults: a systematic review", n.d.; Novaković et al., 2014). Note that family's SES might be endogenous because relative age might influence family's SES, as found in Denmark Landersø et al. (2020), and, vice-versa, SES might influence relative age, because families with different SES might target (more or less consciously) different periods of delivery, as found in some Anglo-Saxon countries (e.g., in the US (Clarke et al., 2019; Buckles & Hungerman, 2013; Dhuey & Lipscomb, 2010) and in Australia (Gans & Leigh, 2009)). There is evidence of this effect also from China (Huang et al., 2020). Various aspects of this phenomenon are a matter of debate though, because it depends on local characteristics, such as social norms and tax incentives (Dickert-Conlin & Elder, 2010). This might not be an issue in our study because for at least three reasons. First, we control for country fixed-effects. Second, results from balance tests in Tabel A.3 in the Appendix suggest that in Europe, on average, families with different SES do not target different dates of birth. Third, we conduct robustness checks, where the main analyses are replicated without family SES, and the results are equivalent.

Our analyses additionally control for unobservable 'season-of-birth effects.' Bound and Jaeger (Bound & Jaeger, 2000) explain that winter-born babies might be more likely to develop health issues, such as mental disabilities and multiple sclerosis, while Spring-born babies might be more likely to become shy. The variable for season of birth is proxied by the month of birth within the calendar year (henceforth, calendar month) and ranges between 0 (January, the reference month) and 11 (December). There are a number of additional studies on the effect of season of birth (e.g. Currie & Schwandt (2013); Buckles & Hungerman (2013)).

Finally, the analyses account for wave and country fixed-effects. Among other unobservable characteristics, country fixed-effects allow us to control for country-specific expected age-at-school start effects.

3 Methods and Results

Methods

We study relative age effects on food choices and dietary habits with a two-stage least square. The second stage is illustrated by Equation [2]:

$$Y_i = \beta_0 + \beta_1 \widehat{RA_i} + \beta_2 \widehat{AA_i} + \mathbf{X_i}\zeta + \mathbf{FE_i}\delta + \mu_i \quad (2)$$

Index i is the individual student. Y_i is one of the outcome variables. $\widehat{RA_i}$ and $\widehat{AA_i}$ are predicted relative and absolute age, obtained from the first stage.[14] The estimate of β_1 is reported in Tables 2 and Figure 2, 3, and 4. $\mathbf{X_i}$ is a vector of demographic control variables, that is, gender, family SES, and the presence of both parents at home. $\mathbf{FE_i}$ is a vector of fixed effects, that is, wave, country, and calendar month of birth–which proxies season of birth.

There are two distinct first stages, one for RA and one for AA–since both of them are endogenous. These first stages are illustrated in Equation [3]:

$$Endogenous_i = \gamma_0 + \mathbf{ERA_i}\gamma + \zeta EAA_i + \mathbf{X_i}\iota + \mathbf{FE_i}\phi + \nu_i \quad (3)$$

'Endogenous' is either RA or AA. $\mathbf{ERA_i}$ is the vector of academic months of birth, that is, expected relative age, while EAA is expected absolute age. Thus, ERA is separated into dummies as suggested in Angrist and Pischke Angrist & Pischke (2008). After Equation [3] is regressed on both RA and AA, we predict $\widehat{RA_i}$ and $\widehat{AA_i}$, which are used in Equation [2].

Notice that, because of the variation in cutoff dates, the correlation between the instruments (i.e., the dummies for expected relative age, that is, the academic months of birth) and the dummies for calendar month of birth is low. Table A.5 in the Appendix shows that the variance inflation factors for both ERA and season-of-birth from the first stage are low: all of them are below 4, and the mean is 3.62; this is well below the 10-threshold, beyond which multicollinearity could be a problem. Figure A.1 in the Appendix illustrates why academic month of birth–which depends from the country cutoff date–differs from calendar month of birth–which starts with January all over the world.

[14]For the econometric analyses, AA is centered around the mean, so that the estimate can be meaningfully interpreted.

Results

Table 2 shows the impact of relative age on the ten outcomes under consideration.

Table 2: Two-stage least square estimates of relative age effects on all ten outcomes.

	Outcome				
	Objective overweight	Subjective overweight	On a diet	Vegetables	Fruits
Relative age	-0.020***	-0.021***	-0.022***	0.024***	0.022***
	(0.005)	(0.006)	(0.007)	(0.006)	(0.006)
N	374,064	577,691	457,398	572,881	574,055
	Sweets	Soft drinks	Hungry to bed	Breakfast school	Breakfast weekend
Relative age	-0.015**	-0.023***	-0.014**	0.024***	0.004
	(0.006)	(0.006)	(0.006)	(0.006)	(0.003)
N	572,962	573,242	343,414	548,696	554,528

Note: Second stage estimates from the 2SLS. All outcomes are investigated with the same model specification: the outcomes is regressed on predicted relative age, predicted and centered absolute age, gender, family's socio-economic status, wave, country, and season of birth fixed-effects. Clustered standard errors at the level of class in parentheses. ***, **, * indicate significance at 1%, 5% and 10%, respectively.

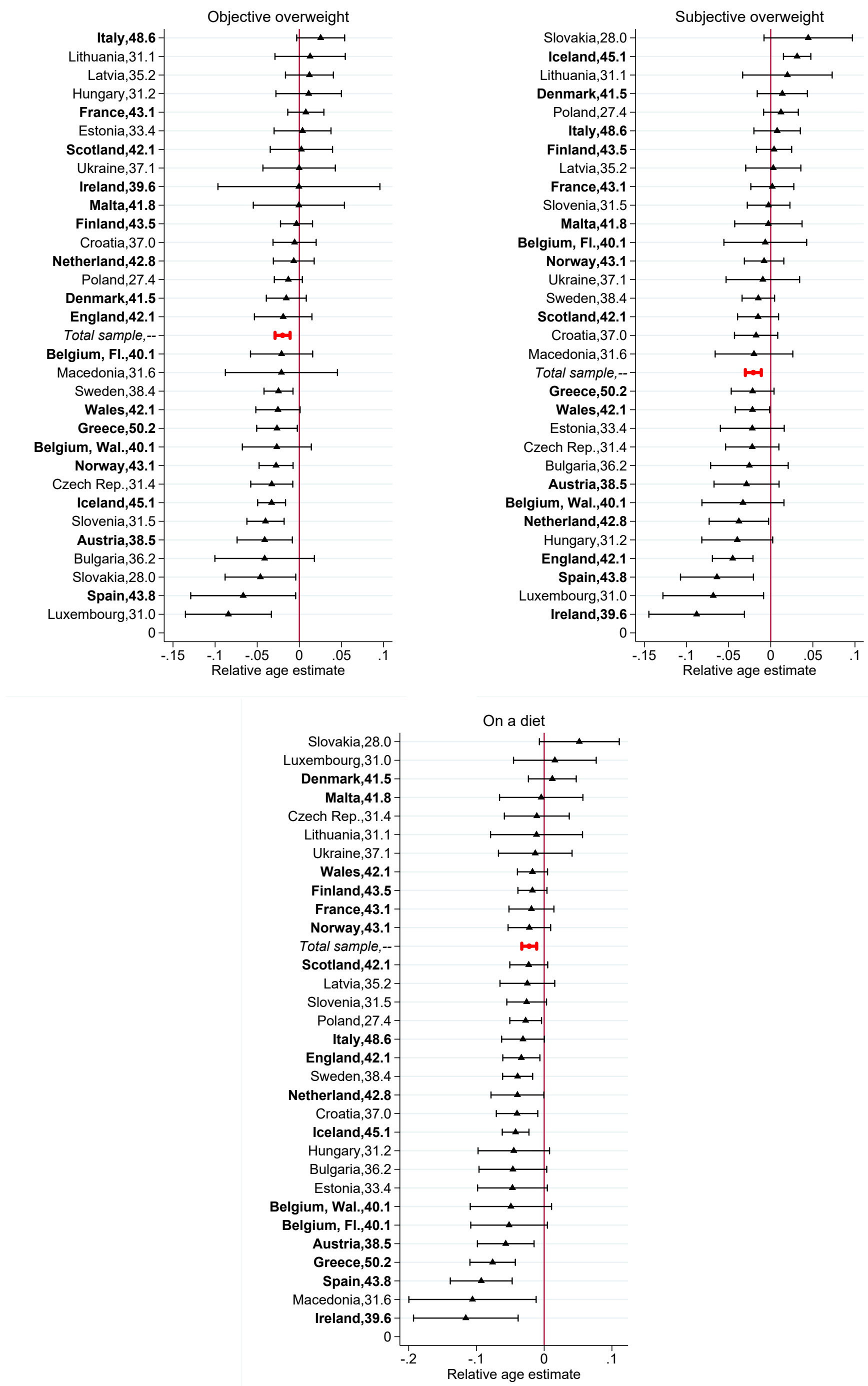
A one-year increase in relative age (i.e., the theoretical maximum age difference between students in the same school class) decreases the likelihood of being objectively and subjectively overweight by 2%, while it decreases the likelihood of being on a diet by 2.2%.[15] A one-year increase in relative age increases the likelihood of consuming at least five days a week vegetables by 2.4% and fruit by 2.2%, while it decreases the likelihood of regular consumption of candies and soft drinks by 1.5% and 2.3%, respectively. A one-year increase in relative age reduces a student's probability of going to bed hungry at least sometimes by 1.4%, while it increases the likelihood of having breakfast each day of the school week by 2.5%. In contrast, relative age does not seem to affect the probability that students have breakfast on weekends. Complete results and secondary statistics are included in Table A.6, Table A.7, and Table A.8 in the Appendix.

[15] To obtain the effect of a one-month increase, one oughts to divide the estimated effect by 12.

Generally, these tests reject the null hypothesis that the instruments are not correlated with the endogenous variable and that they are only weakly correlated, respectively. For the latter test, the F statistics are beyond critical values (Stock & Yogo, 2005). Moreover, overidentification tests fail to reject the null hypothesis that the instruments are uncorrelated with the second-stage error term.

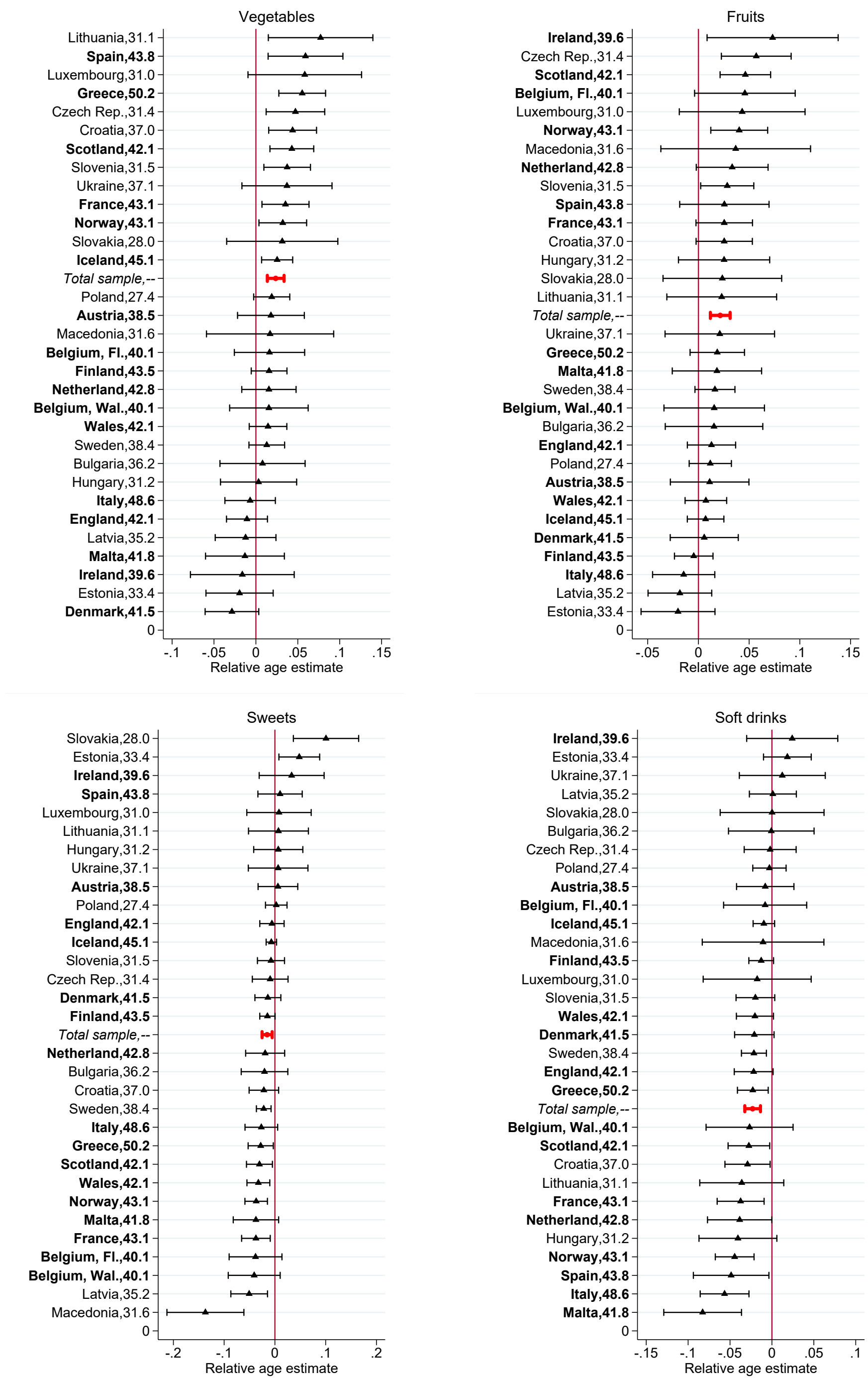
In the analyses at country-level, we focus on the variation in the sign of the estimates. While variation in the magnitude of the estimates is interesting, it is a natural occurrence given that we considere many very different countries. Figure 2, 3, and 4 report relative age coefficients on all outcomes, for individual countries, with 90% confidence intervals. For comparison sake, these figures include estimates from the pooled sample. The x-axis reports country specific relative age effects, whereas the y-axis reports the name of the country, with the Alternative Health Eating Index (AHEI) score. Countries in bold have an AHEI larger than the median among the countries in the sample. Table A.2 in the Appendix reports the AHEI score for each country and the dummy variable used to divide the countries (i.e., equal to 1 if the AHEI is above the median, and 0 otherwise).

Figure 2: Relative age effects on objective and subjective overweight, and on being on a diet, per country.



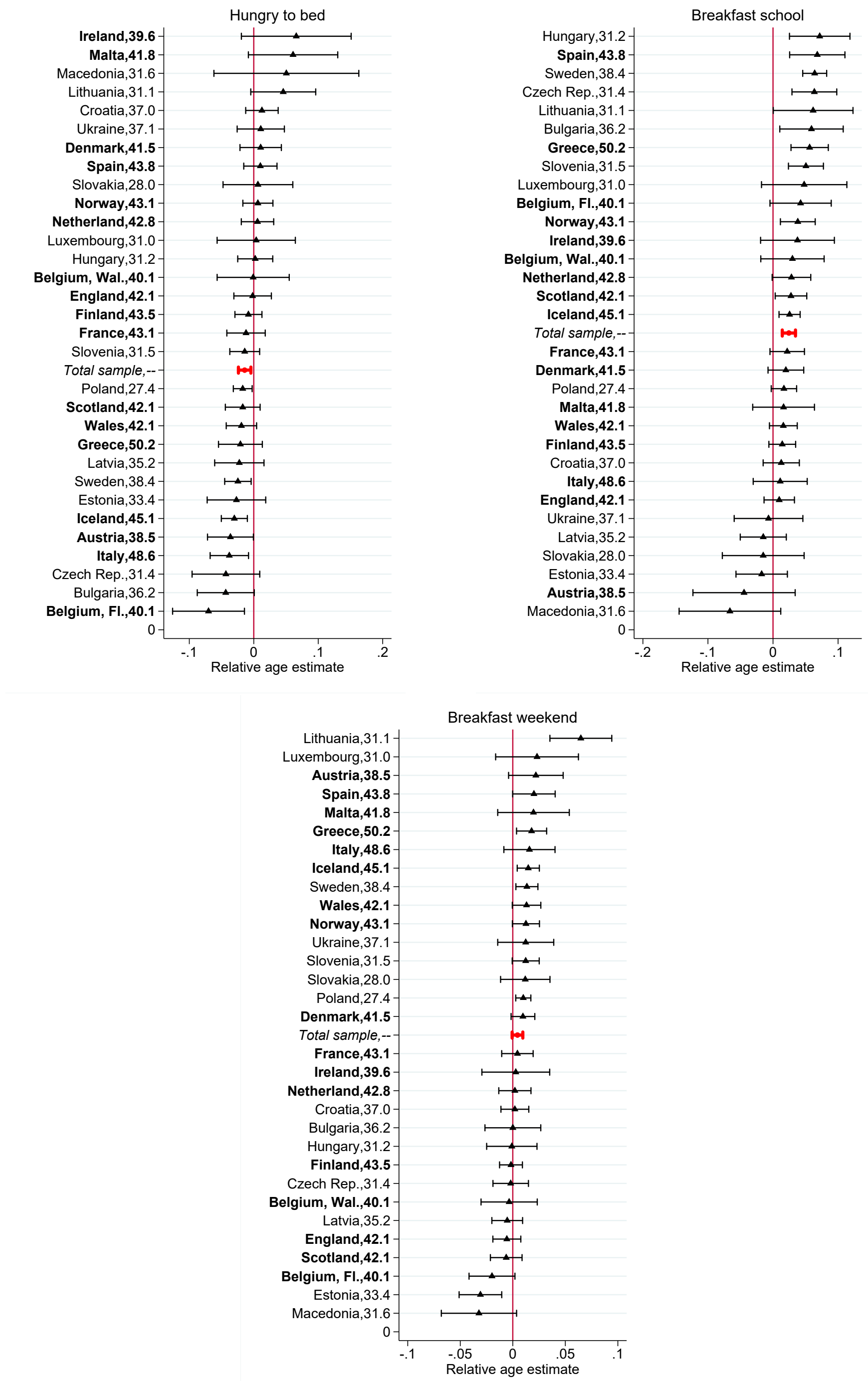
Note: The model specification is similar to Equation 1, except for country and season-of-birth fixed-effects that cannot be included due to perfect collinearity. Greenland is not included due small N. For comparability sake, the estimate for the 'Total sample' is obtained with this specification. Countries in bold have an Alternative Healthy Eating Index (AHEI) larger than the median. The x-axis reports country specific relative age effects, whereas the y-axis reports the name of the country, with the AHEI score. 90% confidence intervals are reported.

Figure 3: Relative age effects on consumption of vegetables, fruits, sweets, and soft-drinks, per country.



Note: The model specification is similar to Equation 1, except for country and season-of-birth fixed-effects that cannot be included due to perfect collinearity. Greenland is not included due small N. For comparability sake, the estimate for the 'Total sample' is obtained with this specification. Countries in bold have an Alternative Healthy Eating Index (AHEI) larger than the median. The x-axis reports country specific relative age effects, whereas the y-axis reports the name of the country, with the AHEI score. 90% confidence intervals are reported.

Figure 4: Relative age effects on hungry to bed, consumption of breakfast on school days and on weekend days, per country.



Note: The model specification is similar to Equation 1, except for country and season-of-birth fixed-effects that cannot be included due to perfect collinearity. Greenland is not included due small N. For comparability sake, the estimate for the 'Total sample' is obtained with this specification. Countries in bold have an Alternative Healthy Eating Index (AHEI) larger than the median. The x-axis reports country specific relative age effects, whereas the y-axis reports the name of the country, with the AHEI score. 90% confidence intervals are reported.

There appears to be little between-country variation in the estimates, this observation suggests that the main results are highly externally valid. Many estimates are not statistically significant at 10% level, and this is not surprising since the country subsamples are much smaller than the pooled sample. However, if we focus on the sign of the estimates, we observe that relative age effects rarely have a different direction from those of the main analyses.

These figures provide an additional insight. In general, relative age effects do not seem to depend on the country-specific food culture, as proxied by the AHEI score; however, in countries with a poorer diet (i.e., countries not in bold font, where the AHEI is equal to, or lower than, the median), there seems to be no effect of relative age on the consumption of vegetables, sweets, soft-drinks, and fruits. This insight is confirmed by additional analyses where we repeat the main analyses on two different subsamples, based on whether the student is in a country with an AHEI equal or lower than its median. These analyses are reported in full in the replication package.

4 Discussion

This study shows that, overall, relative age affects dietary behaviors, which could partly explain why previous studies identify a higher risk of suffering from body-weight issues among relatively young students (Anderson et al., 2011; Fumarco et al., 2020). In sum, relatively young students have a less balanced diet. Moreover, relatively old students are more likely to eat breakfast daily and less likely to go to bed hungry. Finally, relatively young students exhibit a higher likelihood of dieting.

This study first contribution is to the literature on school determinants of dietary patterns among adolescents. Previous studies have focused on the effects of school peers' dietary and weight management behaviors (Yakusheva et al., 2011; Fortin & Yazbeck, 2015; Gwozdz et al., 2019), as well as on schools meals provision (Au et al., 2016; Frisvold, 2015; Lundborg et al., 2022). This paper shows that also relative age is an important determinant of dietary behaviors, although we cannot investigate mechanisms behind this effect.

This study has a twofold contribution to the literature on relative age effects. First, previous studies provide evidence that relatively young students tend to perform worse in school (Bedard & Dhuey, 2006; Elder & Lubotsky, 2009; Peña, 2017; Sprietsma, 2010) and exhibit lower non-cognitive abilities and poorer well-being (Dhuey & Lipscomb, 2008, 2010; Fumarco & Baert, 2019; Fumarco et al., 2020; Fumarco & Schultze, 2020; A. M. Mühlenweg, 2010; A. Mühlenweg et al., 2012; Patalay et al., 2015; Schwandt & Wuppermann, 2016; Thompson et al., 2004); relative age differences in dietary behaviors might explain part of these effects. Moreover, previous studies show that regular intakes of breakfast, fruits, and vegetables are associated with higher levels of school performance (Kim et al., 2016), while the consumption of soft drinks is linked to lower school performance. Additional studies document a positive relationship between diet quality and academic performance, while others find that unhealthy eating habits are accompanied by lower levels of well-being among adolescents (Florence et al., 2008; Puloka et al., 2017). Relatively younger students already underperform at school (Bedard & Dhuey, 2006); the worse diet, combined with lower frequency of breakfasts on school days, might generate a vicious circle and further increase performance gaps they suffer.

Second, while most literature on relative age effects have great internal validity, concerns about external validity are not usually addressed, as they are often based on administrative data from one country, with specific characteristics. The most famous exception is the seminal study from Bedard & Dhuey (2006). Our heterogeneity analyses from more than 30 very different countries show that the main results are greatly externally valid, and that country-wise diet quality does not seem to play a role, although there might be a variation in the effect on the consumption of certain foods and drinks. This investigation at the country-level additionally contributes to a broader recent debate in economics on results external validity (Alubaydli & List, 2015; List, 2020; Bo & Galiani, 2021; List, 2022).

Although not originally planned in this study, our findings contribute to the public debate on the school starting time as well. This debate reached the apex in a famous 2013-Twitt by Arne Duncan, then US Secretary of State for Education, that read: 'Let teens sleep, start school later.' We find that there is a relative age effect on the frequency of breakfast on school days, but not on weekend days. We speculate that there might be a compensatory behavior during school days. In particular, relatively younger students might tend to give up on breakfast at higher frequency, in exchange for more sleep time during the week, when they have to wake up early.

Since that Twitt, little has been done to change the starting school time in the US and, similarly, there is no hint to a change in the school time-schedule in Europe. In the US, early start time was still criticized in 2022 by the CDC.

The limitation of this study is that we cannot answer the question of why relative age affects dietary behaviors. Knowing the mechanisms would have important policy implications; however, based on the existing literature, we can envisage some mechanisms. For example, the discomfort coming from lagging behind in school (Bedard & Dhuey, 2006), from having few friends (Fumarco & Baert, 2019), from being stigmatized for being (mis)diagnosed with attention-deficit and hyperactivity disorder (Layton et al., 2018), might mediate the effect of relative age on students' life-satisfaction and general mental health, which in turn might affects relatively young students' dietary behaviors.

One possible way to reduce the gaps faced by relatively young students would be to reduce the maximum hypothetical age gap between classmates (e.g., break the cohort in two parts, so that there is at most a 6-month difference between classmates rather than 12 months); it would be important and interesting to conduct pilot tests with this respect. This reform would increase the number of classes, which is expensive and logistically hard to manage. However, the educational system is historically opened to important interventions. A good example is the so called 'G8', in Germany; over a period of about 15 years, at different points in time across federal states, the gymnasium was shortened from 9 to 8 years, while the curriculum required for graduation was held constant, increasing the amount of daily time spent in school (Meyer et al., 2019; Hofmann & Mühlenweg, 2018; Krekel, 2017).

There could be cheaper and less burdensome alternative interventions; for example, students' performance assessment could be reformed by adopting age-related grade allowances, which are currently used in some parts of England (Peña, 2022). This intervention would reduce education performance gaps, which would ease relatively young students' mental burden and might reduce dietary gaps.

These two examples of interventions are simple speculative exercises. In order to gain more insights on the mechanisms and on possible intervention to mitigate relative age effects, pilot experiments in school should be conducted. Relative age effects are not mere statistical curiosities without policy implications and, although interventions might be costly, they promise positive effects on public health and healthcare expenses.

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Appendix

Table A.1: Quantity of observations per country/territory, per wave.

	Wave					
	2001/2	2005/6	2009/10	2014/15	2017/18	All waves
Country	N	N	N	N	N	N
Austria	4,150	4,757	4,679	3,313	3,794	20,693
Belgium, Flanders	1,345	3,113	3,029	3,230	3,013	13,730
Belgium, Wallonia	3,026	3,589	3,080	4,845	4,146	18,686
Bulgaria	0	4,826	0	4,639	3,199	12,664
Croatia	4,270	4,680	6,058	5,507	4,687	25,202
Czech Republic	5,006	0	4,324	5,041	11,265	25,636
Denmark	4,468	5,319	3,921	3,784	3,112	20,604
Estonia	3,279	4,202	4,131	4,001	4,592	20,205
Finland	5,143	5,143	6,496	5,810	0	22,592
France	7,393	5,736	5,457	5,168	8,599	32,353
Greece	0	0	4,808	4,078	3,807	12,693
Greenland	0	0	198	141	556	895
Hungary	3,985	3,450	4,569	3,737	3,456	19,197
Iceland	0	8,480	8,747	9,160	3,643	30,030
Ireland	1,951	3,730	1,859	3,366	3,120	14,026
Italy	4,313	3,867	4,734	3,906	4,025	20,845
Latvia	3,225	4,096	4,053	4,924	3,946	20,244
Lithuania	5,586	5,575	5,221	0	1,507	17,889
Luxembourg	0	2,889	2,968	2,192	2,315	10,364
Malta	1,853	0	0	2,227	1,936	6,016
Netherlands	3,778	3,796	4,076	3,862	4,206	19,718
North Macedonia	3,593	4,749	3,434	4,096	4,072	19,944
Norway	4,943	0	4,050	3,144	2,891	15,028
Poland	6,245	5,475	4,190	4,068	4,953	24,931
Slovakia	0	0	4,468	4,997	0	9,465
Slovenia	3,894	5,070	5,322	4,795	5,574	24,655
Spain	5,418	7,738	3,861	3,442	2,938	23,397
Sweden	3,778	4,332	6,627	7,471	4,076	26,284
Ukraine	3,943	4,859	5,345	3,095	5,263	22,505
England	3,822	4,697	3,437	5,261	3,084	20,301
Scotland	4,381	6,130	6,668	5,672	4,799	27,650
Wales	3,771	4,384	5,326	5,050	0	18,531
Total	109,227	128,406	140,087	139,060	122,629	639,409

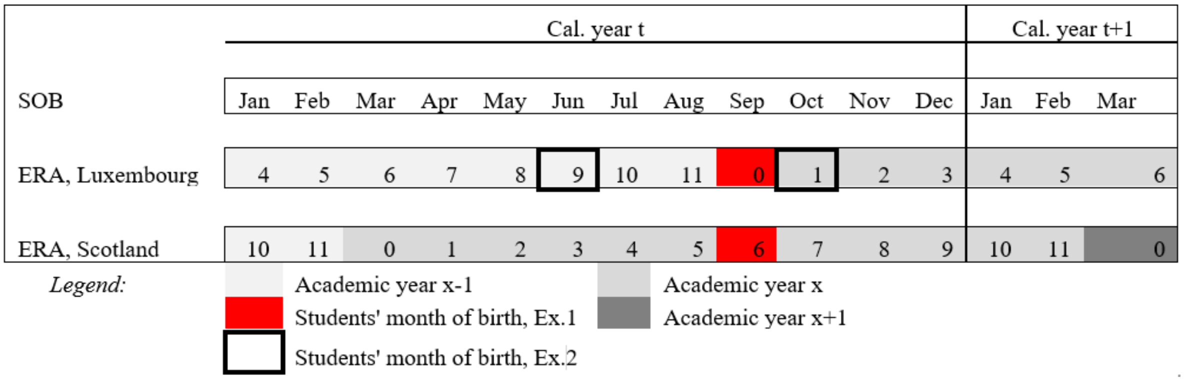
Note: Flanders and Wallonia as well as Denmark mainland and Greenland hold separate surveys within Belgium and Denmark, respectively.

Table A.4: First stage results.

Variables	ERA	AA
	(1)	(2)
ERA 1	0.001	-0.021***
	(0.004)	(0.003)
ERA 2	-0.040***	-0.062***
	(0.003)	(0.002)
ERA 3	-0.078***	0.037***
	(0.003)	(0.002)
ERA 4	-0.154***	-0.004**
	(0.003)	(0.002)
ERA 5	-0.205***	-0.040***
	(0.004)	(0.002)
ERA 6	-0.198***	0.043***
	(0.004)	(0.002)
ERA 7	-0.243***	0.011***
	(0.004)	(0.002)
ERA 8	-0.322***	-0.043***
	(0.004)	(0.002)
ERA 9	-0.346***	0.020***
	(0.004)	(0.003)
ERA 10	-0.336***	0.010***
	(0.004)	(0.003)
ERA 11	-0.341***	-0.004
	(0.005)	(0.003)
EAA	0.016***	0.990***
	(0.001)	(0.001)
Obs.	577,691	596,387
Adj. R2	0.180	0.967

Note: ERAs are dummies for academic month of birth, that is, expected relative age. EAA is expected absolute age. ERA is expected relative age. AA is absolute age. Clustered standard errors at the class level in parentheses. ***, **, * indicate significance at 1%, 5% and 10%, respectively.

Figure A.1: Season of birth and expected relative age; example with Luxemburgish and Scottish students.



Note: This figure illustrates two examples. Red boxes illustrate Example 1. Here, there are two children born in September of the same calendar year t–and thus in the same season of birth (SOB), but in countries with different cutoff dates: September 1st in Luxembourg and March 1st in Scotland. Thus, they have different Expected Relative Age (ERA). Cells with the thick boarder illustrate Example 2. The thick-boarder cell under June shows that this student's ERA is 9, being born on the 9th month of academic year x-1, in Luxembourg. However, this student was retained and is placed in academic year x, where the oldest regular student is born four months later, in the thick-boarder cell under October. Thus, this student is about four months older than the actual oldest regular student in their class.

Table A.2: Countries cutoff dates, index and dummy for the Alternative Health Eating Index.

Country	Cutoff month (1)	Alternative Healthy Eating dummy (2)	Alternative Healthy Eating Index (3)
Austria	Sep	0	38.5
Belgium, Flanders	Jan	1	40.1
Belgium, Wallonia	Jan	1	40.1
Bulgaria	Jan	0	36.2
Croatia	Apr	0	36.9
Czech Republic	Sep	0	31.4
Denmark	Jan	1	41.5
England	Sep	1	42.1
Estonia	Oct	0	33.3
Finland	Jan	1	43.5
France	Jan	1	43.1
Greece	Jan	1	50.2
Greenland	Jan	-	-
Hungary	Jul	0	31.2
Iceland	Jan	1	45.1
Ireland	Jan	0	39.6
Italy	Jan	1	48.6
Latvia	Jan	0	35.2
Lithuania	Jan	0	31.1
Luxembourg	Sep	0	31
Malta	Jan	1	41.7
Netherlands	Oct	1	42.8
Norway	Jan	1	43.1
North Macedonia	Jan	0	31.5
Poland	Jul	0	27.3
Scotland	Mar	1	42.1
Slovakia	Sep	0	27.9
Slovenia	Jan	0	31.5
Spain	Jan	1	43.8
Sweden	Jan	0	38.4
Ukraine	Jan	0	37.1
Wales	Sep	1	42.1
Median			39.6

Note: The Alternative Healthy Eating dummy equals 1 if the AHEI is above the median, and 0 otherwise.

Table A.3: Conditional correlation between expected relative age and main control variables.

Variables	Female	Parents	SES: Low	SES: Medium	SES: High
	(1)	(2)	(3)	(4)	(5)
ERA 1	0.000	-0.003	-0.001	0.001	0.000
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
ERA 2	0.005	0.001	-0.000	-0.001	0.001
	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
ERA 3	0.002	-0.002	-0.005	0.002	0.004
	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
ERA 4	0.004	-0.001	-0.001	-0.002	0.003
	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
ERA 5	0.001	-0.001	0.002	-0.000	-0.002
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
ERA 6	0.004	0.005	0.000	-0.003	0.002
	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
ERA 7	0.010**	0.002	0.003	-0.001	-0.002
	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)
ERA 8	0.006	0.001	-0.000	0.002	-0.001
	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
ERA 9	0.004	0.001	-0.002	0.003	-0.002
	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
ERA 10	0.003	-0.005	0.003	0.001	-0.004
	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)
ERA 11	0.003	-0.004	0.004	-0.000	-0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Obs.	616,973	596,387	616,973	616,973	616,973
Adj. R2	0.001	0.038	0.117	0.003	0.100

Note: ERAs are dummies for academic month of birth, that is, expected relative age. SES is socio-economic status. Clustered standard errors at the class level in parentheses. ***, **, * indicate significance at 1%, 5% and 10%, respectively.

Table A.5: Variance inflation factor of expected relative age and season of birth, from first stage.

Variables	VIF
ERA	
1	3.39
2	3.30
3	3.37
4	3.15
5	3.85
6	3.08
7	3.75
8	3.08
9	3.27
10	3.15
11	3.43
Season of birth dummies	
1	3.35
2	3.39
3	3.39
4	3.21
5	3.85
6	3.07
7	3.74
8	3.06
9	3.29
10	3.16
11	3.46
Mean VIF	3.62

Note: ERAs are dummies for academic month of birth, that is, expected relative age. Season of birth dummies represent months within the calendar year. VIF's from in this table are obtained from the full first stage. Thus, the mean VIF reported here is not the mean VIF based on only the 22 variables in the table.

Table A.6: Relative age effects on dietary outcomes.

Variables	Objective overweight (1)	Subjective overweight (2)	On a diet (3)
RA	-0.020***	-0.021***	-0.022***
	(0.005)	(0.006)	(0.007)
AA	-0.001***	0.015***	0.024***
	(0.000)	(0.001)	(0.001)
Female	-0.062***	0.121***	0.135***
	(0.001)	(0.001)	(0.002)
Parents	-0.017***	-0.041***	-0.041***
	(0.001)	(0.002)	(0.002)
SES: Medium	-0.012***	-0.014***	-0.011***
	(0.002)	(0.002)	(0.002)
SES: High	-0.034***	-0.038***	-0.025***
	(0.001)	(0.002)	(0.002)
Obs.	374,064	577,691	457,398
Adj. R2	0.019	0.037	0.042
Ancillary tests			
Under id. test: Lagrange	5,674	7,422	5,742
Multiplier st. [p-value]	[0.001]	[0.001]	[0.001]
Weak id.: F-st.	639.2	983.9	824.2
Over-id. test:	10.570	6.536	5.438
J st. [p-value]	[0.392]	[0.768]	[0.860]

Note: Second stage estimates from the 2SLS. RA is relative age, AA is absolute age and it is centered around the mean to accommodate a more meaningful interpretation. SES is socio-economic status. Control variables include additionally include vectors for wave, country, season of birth fixed-effects. Clustered standard errors at the level of class in parentheses. ***, **, * indicate significance at 1%, 5% and 10%, respectively.

Table A.7: Relative age effects on eating regime.

Variables	Vegetables	Fruits	Sweets	Soft drinks
	(1)	(2)	(3)	(4)
RA	0.024***	0.022***	-0.015**	-0.023***
	(0.006)	(0.006)	(0.006)	(0.006)
AA	-0.010***	-0.029***	0.017***	0.018***
	(0.001)	(0.000)	(0.000)	(0.001)
Female	0.081***	0.074***	0.017***	-0.082***
	(0.001)	(0.001)	(0.001)	(0.001)
Parents	0.037***	0.035***	-0.003*	-0.037***
	(0.002)	(0.002)	(0.002)	(0.001)
SES: Medium	0.036***	0.039***	0.003**	-0.009***
	(0.002)	(0.002)	(0.002)	(0.002)
SES: High	0.085***	0.080***	0.004**	-0.021***
	(0.002)	(0.002)	(0.002)	(0.002)
Obs.	572,881	574,055	572,962	573,242
Adj. R2	0.059	0.058	0.089	0.085
Ancillary tests				
Under id. test: Lagrange	7,423	7,423	7,427	7,433
Multiplier st. [p-value]	[0.001]	[0.001]	[0.001]	[0.001]
Weak id.: F-st.	1,206	1,207	1,208	1,209
Over-id. test:	15.10	7.264	11.850	9.066
J st. [p-value]	[0.128]	[0.700]	[0.295]	[0.526]

Note: Second stage estimates from the 2SLS. RA is relative age, AA is absolute age and it is centered around the mean to accommodate a more meaningful interpretation. SES is socio-economic status. Control variables include additionally include vectors for wave, country, season of birth fixed-effects. Clustered standard errors at the level of class in parentheses. ***, **, * indicate significance at 1%, 5% and 10%, respectively.

Table A.8: Relative age effects on eating intensity.

Variables	Hungry to bed (1)	Breakfast school (2)	Breakfast weekend (3)
RA	-0.014**	0.024***	0.004
	(0.006)	(0.006)	(0.003)
AA	-0.007***	-0.034***	-0.013***
	(0.000)	(0.001)	(0.000)
Female	-0.026***	-0.068***	0.008***
	(0.001)	(0.001)	(0.001)
Parents	-0.039***	0.079***	0.020***
	(0.002)	(0.002)	(0.001)
SES: Medium	-0.033***	0.023***	0.008***
	(0.002)	(0.002)	(0.001)
SES: High	-0.053***	0.048***	0.019***
	(0.002)	(0.002)	(0.001)
Obs.	343,414	548,696	554,528
Adj. R2	0.031	0.056	0.018
Ancillary tests			
Under id. test: Lagrange	4,188	6,645	7,158
Multiplier st. [p-value]	[0.001]	[0.001]	[0.001]
Weak id.: F-st.	701.9	1,087	1,156
Over-id. test:	8.912	2.215	6.200
J st. [p-value]	[0.540]	[0.994]	[0.798]

Note: Second stage estimates from the 2SLS. RA is relative age, AA is absolute age and it is centered around the mean to accommodate a more meaningful interpretation. SES is socio-economic status. Control variables include additionally include vectors for wave, country, season of birth fixed-effects. Clustered standard errors at the level of class in parentheses. ***, **, * indicate significance at 1%, 5% and 10%, respectively.

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