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Causes of Increased Energy Intake Among Children in the U.S., 1977–2010

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Abstract

Background—Changes in total energy (TE) intake have been reported among children and adolescents, but the extent to which the components of total energy—energy density (ED); portion size (PS); and the number of eating/drinking occasions (EO)—drive these changes is unknown.

Purpose—The objective of the current study was to examine the relative contribution to changes in daily total energy.

Methods—Using cross-sectional nationally representative data from the Nationwide Food Consumption Survey (1977–1978); the Continuing Survey of Food Intake of Individuals (1989–1991); and the National Health and Nutrition Examination Surveys (1994–1998 and 2005–2010) for children and adolescents (aged 2–18 years), changes in total energy (kcal/day) are mathematically decomposed to determine the relative contributions of its three component parts: portion size (g/EO); energy density (kcal/g/EO); and eating/drinking occasions (#). Analyses were completed in 2012.

Results—Over the full period, there was an increase in total energy intake (+108 kcal/day) and the number of daily eating/drinking occasions (+1.2). The average portion size per eating/drinking occasion increased between 1977–1978 and 1989–1991, then dropped by about 85g/EO between 1989–1991 and 2005–2010. The average energy density per eating/drinking occasion has fluctuated over time, reaching its highest level in 2005–2010 (1.24 kcal/g/EO). The decomposition results show that between 1977–1978 and 2005–2010, changes in the number of eating/drinking occasions per day and portion size per eating occasion were the largest contributors to annualized changes in daily total energy (+19 kcal/day/year and −13 kcal/day/year, respectively). Variations in trends were observed for race/ethnicity and parental education subgroups.

Conclusions—These findings highlight potentially important intervention targets for reducing energy imbalances in U.S. youth.

Introduction

The prevalence of overweight among children (aged 2–18 years) increased dramatically between early 1980 and 2000[1,2] and remains very high. Diet quality and nutrient

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composition are viewed as key modifiable factors.[3,4] Changes in energy intake among children and adolescents have been reported in some but not all age/gender groups.[5,6] Research examining potential contributors to changes in energy intake tend to focus on energy density (ED),[7,8] the combination of energy density and portion size (PS),[9] or changes in number of eating/drinking occasions, particularly snacking.[10] Such findings are important because reported energy intake, meal portion size, and meal energy have been positively associated with BMI percentile in boys aged 6–11 years and all children aged 12–19 years.[11]

To our knowledge, however, combinations of these three components have not been examined relative to one another, particularly in children aged 2–18 years. The purpose of the current study was to examine the relative contribution of changes in the frequency of eating and drinking occasions (hereafter called eating occasions [EO]); portion size; and energy density to changes in total energy intake in a nationally representative sample of U.S. children and adolescents between 1977 and 2010. This method has been previously implemented by the authors' group to decompose change in total energy among U.S. adults.[12]

Methods

Study Population

Nationally representative dietary data of children and adolescents (aged 2–18 years) were taken from four U.S. food surveys: the National Food Consumption Surveys (NFCS), 1977–1978 (*n*=12,036); the Continuing Survey of Food Intake of Individuals (CSFII), 1989–1991 (*n*=4008); the National Health and Nutrition Examination's (NHANES) What We Eat in America Survey, 1994–1998 (*n*=8621); and three consecutive, combined, surveys of NHANES: 2005–2006, 2007–2008, and 2009–2010 (NHANES 2005–2010, *n*=8970). Sampling methods and design are described in detail elsewhere.[12–16] The study was approved by the IRB at The University of North Carolina, Chapel Hill. Analyses were conducted in 2012.

Dietary Data

Each of the individual surveys has slightly different methods of dietary data collection, although there is substantial overlap. Briefly, the NFCS 1977–1978 and CSFII 1989–1991 surveys collected dietary intake data over 3 consecutive days using a single interviewer-administered 24-hour dietary recall followed by a self-administered 2-day diet record. The NHANES 1994–1998 and NHANES 2005–2010 surveys, on the other hand, utilized 2 nonconsecutive days of interviewer-administered 24-hour dietary recalls. For participants aged <6 years, interviews were conducted with a proxy (generally, the person most knowledgeable about the child's intake). With children aged 6–11 years, the interviews were conducted with the child, with assistance from their caregiver. To maintain consistency across studies, the first day of available 24-hour recalls were used.

Defining eating occasions, total energy, portion size, and energy density— Eating occasions were self-defined by respondents as either breakfast, lunch, or dinner (meals) or snacks (any other eating occasion). For the purposes of this study, any two snacking occasions reported within 15 minutes of one another were combined. Foods that were reported as having been consumed at the same time (e.g., 12:15PM) but identified by the respondent as two different eating occasions (e.g., a sandwich was called lunch and an apple was called a snack) were assigned to a single eating/drinking occasions (in this case, both were called lunch). Beverages consumed alone (excluding water, for reasons detailed elsewhere[12]) were considered snacks, unless the respondent identified them as a meal. For each respondent, the total number of eating/drinking occasions was summed. This method of assigning meals and snacks has been employed previously.[12,17,18]

For each exam year, a calculation was made of the total daily energy (kcal/day); portion size (g/day); and energy density ((kcal/g)/day) of foods and beverages. Calculations were also made, per eating/drinking occasion, of measures for energy intake (kcal/EO); portion size (g/EO); and energy density ((kcal/g)/EO). These calculations were done for foods and beverages separately, but the average combined food and beverage values were used in the decomposition algorithm.

Decomposition algorithm—Mathematical decomposition has been applied to many measures of changes in health and behavior[19–21] and was previously used by the current authors' group to examine contributions to change in total energy among adults in the U.S.,[12] where this method is described in detail. Briefly, this method operates using the following definition of total daily energy intake:

$$TE\left(\frac{kcal}{d}\right)=PS\left(\frac{g}{EO}\right)\times ED\left(\frac{\frac{kcal}{g}}{EO}\right)\times EO\left(\frac{num}{d}\right),$$

where total daily energy is the result of the average portion size (g/EO) and energy density (kcal/g/EO) of each eating occasion multiplied by the average number of daily eating occasions (num/day). From this, the derivative of the equation was calculated (which represents the proportionate contribution of changes in each of these components to overall changes in total daily energy intake) between any two time periods (e.g., between 1998–1991 and 1994–1998) using the following equation:

$$\Delta TE=\Delta PS(\overline{ED}\times\overline{EO})+\Delta ED(\overline{PS}\times\overline{EO})+\Delta EO(\overline{ED}\times\overline{PS}).$$

The proportionate contribution of each of these three components is then divided by the time between each survey to account for the unequal distribution between years. The final resulting output is interpreted as the annual change in energy (kcal/day/year) attributed to annual change in portion size, energy density, and eating occasions, with the sign indicating the direction of change. Again, a more detailed description of this method can be found elsewhere.[12]

Data Analysis

All analyses were conducted using Stata 12. Estimates were generated using survey commands to account for survey design, weighing, and clustering. All were adjusted to the 1977–1978 age–gender–race/ethnicity sample distribution and are reported as predicted mean (or percentage) and SE. To test for statistical differences in sociodemographic characteristics between years, independent two sided *t*-tests were used, with $p \leq 0.05$ set for significance, and Bonferroni correction used for multiple comparisons.

Results

Daily Trends

The sample population in 1977–1978 was significantly younger and had a higher percentage of non-Hispanic white males with 12 or fewer years of education compared to the later exam years. The population in 1977–1978 also had a lower percentage of Hispanics and a lower percentage of people living at or above 350% poverty income ratio (Table 1).

The average portion size per eating occasion increased from 1977–1978 to 1989–1991 (+13g/EO) and then declined between 1989–1991 and 1994–1998 (−25g/EO) and 1994–1998 and 2005–2010 (−60g/EO). The average energy density per eating occasion fluctuated between exam years. The total number of daily eating/drinking occasions increased between every two exam periods starting in 1989–1991, from 3.9 EO/day in 1977–1978 and 1989–1991 to 5.1 EO/day in 2005–2010 (Table 1). Total daily energy intake increased by 108 kcal/day over the full 30 years, with the largest increase occurring between 1989–1991 and 1994–1998 (+173 kcal/day) and a slight decline between 1994–1998 and 2005–2010 (−85 kcal/day).

By Food and Beverage

The average portion size per eating occasion for foods steadily declined between 1977–1978 and 2005–2010 (−49 g/EO) while the average for beverages increased between 1977–1978 and 1998–1991 (+15g) then declined (−24 g/EO) to its lowest value in 2005–2010 (Figure 1). The energy density of foods increased over this time period, from 2.00 kcal/g/EO in 1977–1978 to 2.19 kcal/g/EO in 2005–2010. Taken together, these changes resulted in larger increases in the total daily energy from foods (+111 kcal/day) compared to beverages (−4 kcal/day) over the past 30 years (data not shown).

Decomposing Change in Total Energy

The three components of total energy have contributed to various degrees to changes in total energy intake (Table 1) over time. For example, between 1977–1978 and 1989–1991, increases in the average portion size per eating occasion accounted for +5 kcal/day/year of the annualized increase in total energy intake, but −31 kcal/day/year of the decline in energy between 1994–1998 and 2005–2010. Changes in the number of eating occasions, on the other hand, accounted for −2 kcal/day/year between 1977–1978 and 1989–1991 but +69 kcal/day/year between 1989–1991 and 1994–1998 (Figure 2).

Between 1989–1991 and 1994–1998; 1994–1998 and 2005–2010; and 1977–1978 and 2005–2010, changes in energy density per eating occasion accounted for the smallest annualized change in total daily energy (−8 kcal/day/year, 8 kcal/day/year, and 5 kcal/day/year, respectively). Over the full 30-year period, the largest contributor to changes in total energy intake was change in the number of daily eating occasions (accounting for +19 kcal/day/year) with a decrease in portion size per eating occasion accounting for −13 kcal/day/year of the annualized change (Figure 2).

Differences by Gender, Race/Ethnicity, and Parental Education

Important differences in energy, portion size, and energy density, respectively, per eating occasion were noted by race/ethnicity and gender, but not parental education between 1977–1978 and 2005–2010 in the full sample (Appendix A, available online at www.ajpmonline.org). Briefly, among non-Hispanic blacks and Hispanics, energy per eating occasion and energy density per eating occasion decreased, and portion size per eating occasion increased, whereas the opposite trends were observed for energy density per eating occasion and portion size per eating occasion among non-Hispanic whites. Both boys and girls decreased energy per eating occasion, but had opposite trends from one another with respect to portion size per eating occasion and energy density per eating occasion (e.g., energy density per eating occasion increased between 1977–1978 and 2005–2010 among girls but decreased among boys).

The three components of total energy intake (portion size, energy density, and eating occasions) contributed differentially to changes in total energy by gender, race/ethnicity, and parental education (differences by age groups were not observed; Appendix B, available online at www.ajpmonline.org). For girls, changes in energy density per eating occasion, portion size per eating occasion, and eating occasions per day contributed roughly equally to changes in total energy intake, although the changes were in opposite directions (Figure 3). Among boys, the largest contributor to changes in annualized total energy intake was eating occasions per day (−16 kcal/day/year) followed by energy density per eating occasion (−8 kcal/day/year). Although girls increased their total daily energy intake over the 30-year period, they still consumed considerably less daily energy than boys (2005–2010 total energy, M (SE): girls, 2422 (83) kcal/day; boys, 3915 (105) kcal/day; Appendix A, available online at www.ajpmonline.org).

Changes in portion size per eating occasion also accounted for the largest change in annualized total energy intake for non-Hispanic blacks and Hispanics, at −15 kcal/day/year and −16 kcal/day/year, respectively, but accounted for +1 kcal/day/year increase in total energy intake among non-Hispanic whites. Among non-Hispanic whites, changes in energy density per eating occasion and the number of eating occasions per day accounted for declines in annualized total energy, whereas energy density per eating occasion accounted for an increase of +51 kcal/day/year for non-Hispanic blacks and +3 kcal/day/year in Hispanics. Changes in eating occasions per day accounted for a small increase in total daily energy intake for non-Hispanic blacks only (Figure 3).

Among parental education groups, declines in the eating occasions per day accounted for the greatest annualized change in total daily energy (among all groups except those whose parents have a college education), ranging from −21 kcal/day/year among those whose parents have less than a high school education to −9 kcal/day/year among those whose parents have some college. All groups except those whose parents have a college education showed a decrease in total energy intake between 1977–1978 and 2005–2010, but the changes were greatest among those whose parents have lower levels of education (Figure 3).

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These 30-year differences (Table 3) are differentially driven by changes in the components of total energy intake. These results are presented between each exam period for each race/ethnicity group in Appendixes C–E (available online at www.ajpmonline.org). As a brief example, changes in eating occasions per day account for a decrease of 63 kcal/day/year between 1977–1978 and 1989–1991 among non-Hispanic blacks, but an increase of +129 kcal/day/year between 1989–1991 and 1994–1998. Differences in the annualized contribution of these three components differed within the same racial/ethnic group over time and between race/ethnicity groups in comparing the same time period (e.g., 1994–1998 to 2005–2010; Appendixes C–E, available online at www.ajpmonline.org).

Discussion

To our knowledge, this is only the second application[12] of a method to decompose changes in energy intake into its component parts, and the first to do so among children. Daily caloric intake for U.S. children and adolescents increased by approximately 130 kcal/day between 1977–1978 and 2005–2010, but has been declining since 1994–1998 from its high of roughly 2050 kcal/day. These findings show that changes in the number of daily eating occasions and portion size of the average eating occasion represent the largest absolute contributors to annualized changes in total energy intake, although their effects are in opposing directions (accounting for +19 kcal/day/year and −13 kcal/day/year, respectively).

Differences by gender, race/ethnicity, and parental education were also observed. As with adults,[12] these findings do not negate the influence of changes in energy density, portion size, or the number of eating occasions on any given *individual's* diet. But to the extent that all energy intake has equal impact on energy balance, this decomposition approach can help guide population-level interventions.

These findings are in line with previous studies from the authors' group documenting a rise in the number of eating occasions, most notably in both the prevalence and number of daily snacking events and their contribution to total energy intake, among U.S. children.[10] Although studies have examined trends in specific aspects of overall eating, such as the prevalence of regularly consuming breakfast[22–24] or family evening meals,[25,26] information on overall trends in meal frequency are limited, and much of the research on children's diets has focused on specific food items,[7,27,28] food components, or trends in eating (e.g., snacking, away-from-home eating)[29–31] as contrasted with examining the total effect of meals.

Further, this work suggests that "supersizing," which has been the subject of a considerable number of scientific and popular media outlets,[32–37] has actually led to decreased energy consumption among children in the U.S. However, there were nuanced changes observed within specific race/ethnicity, gender, and parental education subgroups such that the three components of total energy intake contributed to a greater and lesser extent, and in different directions (i.e., increase or decrease in total energy), over time.

These findings suggest that the influences on total energy intake in children and adolescents of different sociodemographic characteristics vary, and that efforts to reduce energy intake should be multifaceted and targeted to the appropriate audience. This study employs just one possible method of decomposition.[20,21,38,39] Replication or refutation of these findings will prove equally important in helping guide future interventions to reduce caloric intake and related health outcomes in children.

Limitations

This study is not without limitations. First, the method of dietary data collection changed across surveys, most notably the introduction of the five-step multiple pass method of 24-hour recall collection (implemented in NHANES 2005–2006), which differs from previous U.S. Department of Agriculture methodologies. Residual confounding by time as a result of these systematic changes is possible, but bridging studies, which could identify the extent to which this is the case, are not available. Previous bridging studies (from the 1970s and 1980s) found that such shifts did not affect results.[40,41]

Differential probing for water (consumed as a beverage) across study years is another notable limitation. As reported in the authors' work with adults,[12] inclusion of water as a food item had important implications for the calculation of energy density. Specifically, the contribution of energy density to changes in total energy intake was 41.7% with water included compared to 5.4% with water excluded. However, water was differentially reported by survey; thus, the additional water-only eating occasions were excluded to maintain consistency across time.

Some scholars may disagree with the combination of foods and beverages used in the current calculation of energy density, arguing instead for a measure of diet energy density that considered foods and beverages independently. However, the stated purpose of the current study is to examine the whole meal effect (including both food and beverage energy), and the authors believe that it is the *combination* of beverages and foods that equal a meal's overall energy density. Thus, beverages were included in the energy density calculations. Finally, it is possible that children's intakes were misreported, although it is difficult to speculate on its potential effect, as it may differ by the child's weight status,[42–44] child's age,[45] child's method of dietary intake,[46,47] or analytic approach.[48]

Conclusion

Using nationally representative samples of U.S. children and adolescents, this study documents marked changes in the number of eating occasions, total daily portion size, and energy density of foods and beverages consumed. Specifically, these findings show that the average portion sizes of foods and beverages have been decreasing since 1989–1991, while the energy density of each eating occasion, particularly for foods, has gone up slightly over the past 30 years. Further, the number of eating occasions has increased considerably since 1977–1978.

These results suggest that as contributors to increased caloric intake over both this most recent decade and over the full 30-year period, increases in the number of eating occasions and decreases in portion sizes contributed significantly more to the shift in total energy intake than did changes in energy density, although important differences by population subgroups were observed. Teaching children and adolescents to be aware of their eating habits, particularly when it comes to the number of times (and what) they eat may help reduce energy imbalance in this population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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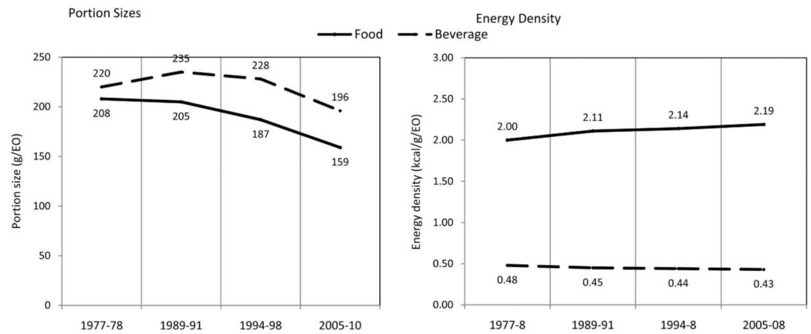

Figure 1.

Average portion size and energy density per eating occasion by food and beverage

Note: Data are from cross-sectional nationally representative samples of children and adolescents (aged 2–18 years) taken from the National Food Consumption Survey, 1977–1978 (*n*=12,036); the Continuing Survey of Food Intake of Individuals II, 1989–1991 (*n*=4008) and 1994–1998 (*n*=8621); and the National Health and Nutrition Examination Survey, 2005–2010 (*n*=8970) standardized to the age, gender, and race/ethnicity distribution of the sample in 1977–1978. EO, eating occasion

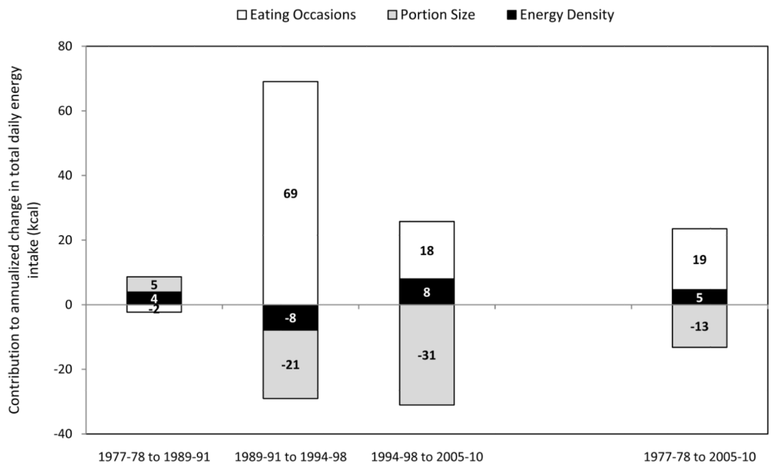

Figure 2.
Annualized energy contribution of portion size, energy density, and eating occasions to total energy intake

Note: Values represent the annualized energy (kcal) contribution of changes in the number of eating occasions, portion size or energy density of each eating occasion to changes in total daily energy (kcal) intake. Data are from cross-sectional nationally representative samples of children and adolescents (aged 2–18 years) taken from the National Food Consumption Survey, 1977–1978 (*n*=12,036); the Continuing Survey of Food Intake of Individuals II, 1989–1991 (*n*=4008) and 1994–1998 (*n*=8621); and the National Health and Nutrition Examination Survey 2005–2010 (*n*=8970) standardized to the age, gender, and race/ethnicity distribution of the sample in 1977–1978.

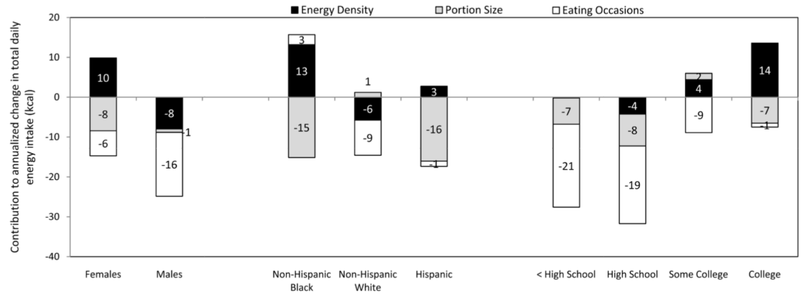

Figure 3.

Annualized energy contribution to total energy intake by gender, race/ethnicity, and parental education, 1977–2008

Note: Values represent the annualized energy (kcal) contribution of changes in the number of eating occasions, portion size or energy density of each eating occasion to changes in total daily energy (kcal) intake. Data are from cross-sectional nationally representative samples of children and adolescents (aged 2–18 years) taken from the National Food Consumption Survey, 1977–1978 (*n*=12,036); the Continuing Survey of Food Intake of Individuals II, 1989–1991 (*n*=4008) and 1994–1998 (*n*=8621); and the National Health and Nutrition Examination Survey, 2005–2010 (*n*=8970) standardized to the age, gender, and race/ethnicity distribution of the sample in 1977–1978.

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Table 1

Characteristics of study populations across exam years[a]

Sample Characteristic	Exam years 1977–1978	1989–1991	1994–1998	2005–2010
Sample size (*n*)	12,036	4,008	8,621	8,970
Age (years)	10.4 ± 0.1	**9.6 ± 0.2***	**9.8 ± 0.1***	**10.0 ± 0.1***
Female (%)	49.8 ± 0.4	49.3 ± 2.0	48.9 ± 0.7	49.0 ± 1.0
Race/Ethnicity (%)				
Non-Hispanic white	75.3 ± 1.9	71.5 ± 1.4	**65.5 ± 2.1***	**60.2 ± 2.3***,**
Non-Hispanic black	15.6 ± 1.4	15.4 ± 1.0	15.7 ± 1.3	14.0 ± 1.2
Hispanic	7.9 ± 1.3	10.6 ± 1.2	13.8 ± 2.0	**19.0 ±1.7***,**
Parents' education (%)				
< High School	22.6 ± 1.1	**14.3 ± 1.0***	**10.9 ± 1.1***	**19.6 ± 1.2****,***
High School	37.9 ± 1.0	**30.0 ± 1.2***	**28.9 ± 1.1***	**23.3 ± 1.2***,**,***
Some College	19.8 ± 0.7	23.1 ± 1.2	**25.1 ± 1.4***	**31.1 ± 1.0***,**,***
College Graduate	19.7 ± 1.0	**32.6 ± 1.5***	35.1 ±2.0	**25.9 ± 1.7***,**,***
Poverty Income Ratio				
<180%	37.7 ± 1.5	35.4 ± 0.7	38.6 ± 1.7	**41.6 ± 1.6****
180% – <350%	41.1 ± 1.2	35.4 ± 2.4	**31.4 ± 1.2***	**26.5 ± 1.0***,**,***
≥350%	21.2 ± 1.1	**29.1 ± 2.8***	30.0 ± 1.7	**31.9 ± 1.7***
Components of Total Energy[b]				
Portion size (g/EO)	427 ± 3	440 ± 3	415 ± 5	355 ± 4
Energy density (kcal/g/EO)	1.19 ± 0.005	1.21 ± 0.011	1.19 ± 0.010	1.24 ± 0.010
Eating occasions (#)	3.9 ± 0.03	3.9 ± 0.04	4.7 ± 0.04	5.1 ± 0.03
Total daily energy (kcal)[b]	1867 ± 15	1883 ± 17	2056 ± 26	1975 ± 16

Note: Boldface indicates significance.

[a]Values are M±SE. Data are from cross-sectional nationally representative samples of children and adolescents (aged 2–18 years) taken from National Food Consumption Survey, 1977–1978 (*n*=12,036); Continuing Survey of Food Intake of Individuals II, 1989–1991 (*n*=4008) and 1994–1998 (*n*=8621); and the National Health and Nutrition Examination Survey 2005–2008 (*n*=6744).

[b]Values are standardized to the age, race, and gender distributions of 1977–1978 sample population using predicted means. Predicting violates the assumption of independence required for performing student's *t*-tests of means; therefore, significant differences are not calculated for these measures.

*Values are different from those for 1977–1978, $p<0.05$ using Bonferroni-corrected two-sided student's *t*-test.

**Values are different from those for 1989–1991, $p<0.05$ using Bonferroni-corrected two-sided student's *t*-test.

***Values are different from those for 1994–1996, $p<0.05$ using Bonferroni-corrected two-sided student's *t*-test.

EO, eating occasions; g, grams; kcal, kilocalories