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The relationship between meal frequency and body mass index in black and white adolescent girls: more is less

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Objective: To document meal frequency and its relationship to body mass index (BMI) in a longitudinal sample of black and white girls from ages 9–19 years.

Design: Ten-year longitudinal observational study.

Subjects: At baseline, 1209 Black girls (539 age nine years, 670 age 10 years) and 1,166 White girls (616 age nine years, 550 age 10 years) were enrolled in the National Heart, Lung and Blood Institute Growth and Health Study (NGHS).

Measurements: Three-day food diaries, measured height and weight and self-reported physical activity and television viewing were obtained at annual in-person visits.

Results: Over the course of the study, the percentage of girls eating ≥3 meals on all 3 days was reduced by over half (15 vs 6%). Participants who ate ≥3 meals on more days had lower BMI-for-age z-scores. Black girls, but not white girls, who ate ≥3 meals on more days were less likely to meet criteria for overweight.

Conclusion: Meal frequency was related to BMI and should be considered when developing guidelines to prevent childhood overweight.


Keywords: meals; body mass index; adolescence; overweight

Introduction

As rates of overweight and obesity have increased exponentially over the past three decades,¹,² identifying targets for obesity prevention in children and adolescents has become a key public health goal. Obesity prevention programs for school-age children have yielded mixed results;³ thus, finding strategies to prevent overweight in children continues to be an important health care priority.

Understanding the relationship between meal patterns and changes in weight may prove helpful in this regard. In studies with adults, eating a greater number of meals per day is associated with lower likelihood of obesity.⁴–⁷ The mechanisms that explain this somewhat paradoxical finding are not yet clearly understood, but may be related to greater thermogenesis after consuming more meals⁸ or higher insulin metabolism.⁹,¹⁰ Alternatively, relevant variables, such as frequency of physical activity and sedentary behaviors, might explain why 'more is less' regarding the relationship between meal frequency and body mass index (BMI). For example, it has been shown that adolescents or adults who eat more frequently also exercise more¹¹,¹² and make healthier food choices.¹³,¹⁴ Researchers have begun to examine the association between meal frequency and BMI in children and adolescents. In two studies based on the Bogalusa Heart Study sample,¹⁴,¹⁵ no significant relationship was found between overweight status and either consuming less than three meals per day (measured categorically as yes/no) or total...
Meal frequency and body mass index

DL Franko et al

number of eating episodes. However, Toschke et al.\textsuperscript{16} reported an association between meal frequency and the prevalence of obesity in a cross-sectional sample of over 4300 German children aged 5–6 years. They noted a dose–response effect, such that the percentage of overweight and obesity decreased substantially with higher meal frequency (it should be noted that in this study ‘meal’ was defined as food ‘conventionally served on a plate’ and included breakfast, lunch, tea and dinner). Specifically, in children whose parents reported they ate three or fewer meals per day, the rate of overweight was 15% and the rate of obesity was 4.2%. As meals increased to four or more, rates dropped to 10.9% and 2.8%, respectively; children who ate five or more meals per day had rates of overweight of 8.1% and of obesity of 1.7%. This association could not be explained by any of the many constitutional (for example, parental obesity), demographic (for example, parental education, gender), or environmental factors (for example, degree of physical activity or television viewing) measured in the study. In addressing the discrepancy between their findings and Nicklas’ reports, Toschke et al.\textsuperscript{16} conducted a power analysis and reported that the direction and size of the finding in the Nicklas’ studies was similar to theirs, but did not reach significance due to an inadequate sample size. In a recently published adolescent study, Thompson and colleagues\textsuperscript{17} confirmed the association using longitudinal data, noting that eating between 4 and 5.9 times per day was negatively associated with a change in BMI z-score. In this study ‘eating events’ (not meals) were measured, defined as eating or drinking episodes that were separated by at least 15 min.

Note that these studies examined consumption of both meals and snacks in relation to BMI.\textsuperscript{14–17} In their comprehensive review, Nicklas and colleagues\textsuperscript{18} pointed out that adolescents with a consistent meal pattern of three meals per day have been found to be leaner than those with an inconsistent pattern\textsuperscript{19} and consistent meals were also found to be associated with better dietary quality. Regularity in meal consumption may serve as an indicator of healthy dietary practices. This is important to examine as healthy dietary practices may assist with control of body weight. Nicklas also highlights the fact that studies looking at the frequency of eating ‘are extremely vulnerable to methodological errors’ and may generate spurious relations because of under-reporting of eating events. In this light, we chose to focus our investigation on meal consumption, as meals are more easily defined than snacks or eating episodes, represent a more structured eating time than snacks, and may indicate healthy dietary behaviors.

We sought to add to the literature on the relationship between meal frequency and BMI with two aims: (1) to document meal frequency from childhood through adolescence in black and white girls; (2) to examine the longitudinal relationship between meal frequency and BMI. Our study is further enhanced by the availability of 3-day food diaries completed by the girls and coded by trained dieticians.

Methods

Participants and recruitment

As reported previously,\textsuperscript{20} the NGHS recruited 2379 black and white girls at three study sites who were 9 or 10 years old at study entry: University of California at Berkeley, University of Cincinnati/Cincinnati Children’s Hospital Medical Center and Westat, Inc./Group Health Association in Rockville, Maryland. Eligible participants identified themselves (using census categories for race/ethnicity) as ‘black’ or ‘white,’ non-Hispanic, with racially concordant parents or guardians. All girls who entered the NGHS had assented, and their parents (or guardian) had consented to their participation. Girls were asked to participate in 10 annual ‘visits.’ Owing to variable annual participation rates, sample sizes varied from visit to visit. Retention rates were very high at visits 2–4 (96, 94 and 91%), declined to a low of 82% at visit 7, and increased to 89% at visit 10.

Measurements and procedure

A complete description of NGHS procedures and measures has been reported.\textsuperscript{20} Briefly, data were collected annually at participating sites or, if the girl was unable to travel to the site, at her home. The Institutional Review Boards of all participating sites approved the study protocol. Only instruments of relevance to the present report are described below.

Meal frequency

The measure of meal frequency was based on 3-day food records that had been previously validated compared to observed intakes during school lunch.\textsuperscript{21} Food records were collected annually for visits 1–5 and then again at visits 7, 8 and 10. Dietitians used age-appropriate materials to instruct girls to record all food and drink, type of meal (breakfast, snack, lunch, and so on), and time of intake for 3 consecutive days that included 2 weekdays and 1 weekend day. In visits 3, 4, 5, 7, 8 and 10, dietitians rated each eating event reported in the food diaries as either ‘meal’ or ‘snack’ and thus only these visits are used in the current analysis. In view of dietitian ratings, for each girl at each visit, the number of days (out of three possible) that a girl consumed three or more meals was computed. Three meals were chosen because it is the typical number of meals consumed over the course of a day in the United States.

Dietitians, trained and certified by the University of Minnesota Nutrition Coordinating Center (NCC), reviewed the completed food records individually with the girls. Supplementary information was not sought from parents, as confidentiality was given a higher priority than additional details on foods or food preparation. Standard probes were used to respond to girls’ questions and to clarify incomplete responses. Default values adapted from NCC were used for missing information on food amounts, types and preparation methods. To minimize the use of defaults, NGHS dietary
staff had a notebook of labels and label pictures to help girls describe foods. Food records were coded and analyzed for nutrients using Food Table Version 19 of the NCC nutrient database.22

**Adiposity**

Annually, centrally trained examiners obtained height (until visit 7) and weight measurements (all visits). BMI was calculated as weight in kilograms divided by height in meters squared. Two BMI-based measures were used as outcome variables in the analysis. First, BMI-for-age z-scores indicated girls’ BMI relative to other girls of the same age. Thompson et al.17 indicated that BMI z-scores provide an indirect age and gender-specific measure of relative adiposity. Because the body composition of adolescent girls changes dramatically with pubertal growth, a relative measure of BMI change is more sensitive and useful than is absolute BMI. Note that a positive change in BMI z-score indicates an increase in relative BMI, whereas the reverse is true for a negative z-score. Second, based on Centers for Disease Control guidelines (http://www.cdc.gov/nccdphp/dnpa/bmi/bmi-for-age.htm), ‘overweight’ was coded as 1 (at or above the 95th percentile of BMI) or 0 (below the 95th percentile).

**Demographic information**

Data regarding race and highest level of parental education were collected at study entry from girls and their parents (or guardians). Race (black or white) was defined by the participant’s self-report at baseline. For the present report, parental education was categorized as 4 or more years of college vs less than 4 years of college. Education was chosen over income as a proxy of socioeconomic status in part because NGHS data were collected at three distinct geographic locations in the United States with different average household income and different price indices (that is, the same amount of income has different purchasing power in Cincinnati compared to Washington, DC). Also, previous research has shown that education is a better predictor of health related outcomes than income.23 Participants’ age was recorded as age at last birthday.

**Assessment of physical activity**

The Habitual Activity Questionnaire (HAQ) adapted from Ku et al.24 was used to measure the physical activity of subjects, and it was administered as a structured interview in years 1, 3, and 5 and self-administered in years 7–10 of the study. The HAQ assessed the type and frequency of participation in activities (sports, physical activities and classes/lessons) outside of school and detailed validation information (using Caltrac activity monitor assessment) has been reported.25 Participants were asked to estimate the weekly frequency of each activity for the school year and summer months. A summary weekly activity score was calculated by multiplying the metabolic equivalents (METs) value of energy expended for each recorded activity by the weekly frequency and the fraction of the year during which each activity was performed. For scoring purposes, the following fractions were assigned to a given time frame: classes/lessons during the year (‘most’ of the year = 1, ‘half’ = 0.5 and ‘small part’ = 0.25); sports/physical activities during the school year (‘most’ of the school year = 0.75, ‘half’ = 0.375 and ‘small part’ = 0.1875); and sports/physical activities during the summer (‘most’ of the summer = 0.25, ‘half’ = 0.125 and ‘small part’ = 0.0625). The final HAQ score (MET-times/week) was the sum of the weekly score for all activity categories (that is, school sports, summer sports, class/lessons) for the previous year.

**Television (TV) viewing**

TV time per week was determined by responses to a questionnaire at all visits except 2 and 4. Participants were provided a list of all TV programs in their viewing area and asked to circle the programs they usually watched, to write down the time spent watching music TV channels, and to write down videos watched during the past 7 days. Staff determined the length of each program and video watched and the total TV time was summed for the week.

**Statistical analysis**

The association between meal frequency and adiposity was estimated using linear regression (model of BMI-for-age z-scores) or logistic regression (model of overweight). These outcomes were modeled as a function of the number of days eating 3+ meals, study year, and the interaction between the two. The models adjusted for study site, demographic variables (parental education, serving as a proxy for socioeconomic status, as well as race and the race by meal frequency interaction) and indicators of energy intake and expenditure (average daily energy intake and two indicators of physical activity, that is hours watching TV per week and physical activity score). The presentation in the results section focuses on the independent variable of primary interest, that is, meal frequency; estimates for the adjustment variables are presented in tabular form but not discussed further. To account for the non-independence among repeated measures within girls, random effects were included in the models;26 specifically, all models included a random intercept representing girl-to-girl variation in year-3 BMI z-scores and overweight. Models estimating non-linear associations between meal frequency and the outcomes did not result in better fit than did models estimating a simple linear association, therefore the latter representation was used in the final models. Direct maximum likelihood was used for unbiased estimation in the presence of missing data.27 Models were estimated using the MIXED and
Results

Table 1 shows number and percent of girls by meal frequency and visit. Between visits 3 and 10, the percentage of girls eating 3+ meals on all 3 days was reduced by over half (15% vs 6%), while the percentage of girls who ate 3+ meals on none of the 3 days nearly doubled (26% vs 51%). Table 2 and Figure 1 show the association between meal frequency and BMI-for-age z-scores. On average, girls who ate 3+ meals on more days had lower BMI-for-age z-scores (main effect of meal frequency, \( P < 0.0001 \); see Table 4 for detailed estimates). For each additional day of eating 3+ meals (holding constant the other variables in the model), BMI-for-age z-scores were estimated to decrease by \(-0.05\) (95% confidence interval (CI), \(-0.3\), \(-0.6\)). However, the slope of this association tended to become less steep in the later visits (meal frequency by visit interaction, \( P < 0.0001 \)).

Tables 3, 4 and Figure 2 show the association between meal frequency and overweight. The main effect for meal frequency was not significant (\( P = 0.20 \)), but there was a significant race by meal frequency interaction (\( P = 0.02 \)). This indicates that, on average, black girls who ate 3+ meals on more days exhibited a decreased likelihood of overweight; for each additional day consuming 3+ meals, black girls were 1.23 times (95% CI: 1.05, 1.50) less likely to be overweight. In contrast, there was no effect of meal frequency on overweight for white girls (Odds ratio = 1.02, 95% CI: 0.84, 1.18). The estimated meal frequency effect did not change across visits (non-significant meal frequency by overweight interaction).

Discussion

Our data indicate that meal frequency is inversely related to BMI for black and white girls between the ages of 9 and 19.
years and that this association holds even when taking into account relevant demographic and energy expenditure variables. For black girls, eating more meals was also related to a decrease in the probability of being overweight. These results are consistent with those found in both adults and children. New to the literature are our findings that this relationship remains significant through middle childhood to late adolescence (though becomes less strong with increasing age) for white girls (BMI z-scores) and black girls (BMI z-scores and overweight).

Consistent with Toschke et al., we found that the relationship between meal frequency and BMI remained even when relevant demographic variables (for example, SES, race) and measures of physical activity and television viewing were taken into account. This finding suggests that encouraging the consumption of meals in girls may be a useful strategy in programs that focus on obesity prevention, in addition to encouraging healthy food choices and exercise. Previous studies have shown the importance of consuming breakfast in relation to BMI; it now appears that eating at least three meals over the course of the day may be helpful in preventing overweight and perhaps should be incorporated into guidelines aimed to prevent childhood obesity. It may be that the old-fashioned ‘meal’ contains more nutritious items than the ‘eat on the run’ or frequent snacking approach that increasingly seems to characterize eating habits.

Our finding that increased meal frequency was related to decreased likelihood of overweight for black girls is important. Black adolescent girls have among the highest rates of overweight in the United States, and strategies that address this problem in this ethnic group have been difficult to develop and implement. A study of black girls (ages 8–10 years) found that the number of meals and snacks consumed was related to energy intake, though not to BMI. In our study, meal frequency was related to overweight, even when taking total caloric intake into account. Why this was true for black girls and not white girls is not entirely clear, but may be related to a greater propensity toward overweight, higher rates of sedentary behaviors, or differences in metabolic rate. Our findings suggest that meal frequency may be a particularly important variable to consider when designing culturally specific obesity prevention and treatment programs.

It is of note that the number of girls who ate three or more meals per day decreased by over half between ages 11 and 19, which is consistent with other studies showing that adolescents’ eating patterns change over time. Potential explanations for this trend include the earlier start of the school day (which may contribute to skipping breakfast), increasing independence, more frequent extracurricular activities and wishes to control weight by skipping meals. However, our data clearly indicate that more frequent meal consumption predicts a healthier BMI. Although it may seem paradoxical that eating more often actually results in weighing less, there is evidence to suggest biological explanations for this relationship. Educating adolescent girls that eating more often may be a productive strategy in managing weight (while staying within appropriate caloric levels) may be a helpful addition to health and nutrition curricula. However, further research is needed to better understand the factors that make it more or less likely that girls will consume three meals a day and on understanding the mechanisms by which meal frequency affects body weight.

In conclusion, it appears that greater meal frequency is associated with a lower risk of increases in BMI, and in black
Table 4  Estimated associations between meal frequency and adiposity, adjusting for visit, study site, parental education, race and indicators of physical activity

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Measure of adiposity</th>
<th>Model of BMI-for-age z-scoresa</th>
<th>Model of overweightb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td></td>
<td>0.4780 (0.0253)***</td>
<td>N/a</td>
</tr>
<tr>
<td>Days with 3+ meals</td>
<td></td>
<td>–0.0472 (0.0077)****</td>
<td>0.91 (0.79,1.05)</td>
</tr>
<tr>
<td>Visit</td>
<td></td>
<td>–0.0001 (0.0032)</td>
<td>1.03 (0.98,1.07)</td>
</tr>
<tr>
<td>Days with 3+ meals × visit</td>
<td></td>
<td>0.0111 (0.0019)****</td>
<td>0.99 (0.96,1.03)</td>
</tr>
<tr>
<td>Days with 3+ meals × race</td>
<td></td>
<td>–0.0017 (0.0091)</td>
<td>0.80 (0.66,0.97)***</td>
</tr>
<tr>
<td>Race = black</td>
<td></td>
<td>0.3158 (0.0447)****</td>
<td>2.64 (1.72,4.07)***</td>
</tr>
<tr>
<td>Site = Berkeley (Maryland is reference)</td>
<td></td>
<td>0.1205 (0.0540)*</td>
<td>1.17 (0.94,1.44)</td>
</tr>
<tr>
<td>Site = Cincinnati (Maryland is reference)</td>
<td></td>
<td>0.0435 (0.0546)</td>
<td>1.03 (0.84,1.27)</td>
</tr>
<tr>
<td>Parent with 4+ years of college</td>
<td></td>
<td>–0.1735 (0.0467)***</td>
<td>0.87 (0.72,1.06)</td>
</tr>
<tr>
<td>Hours of TV per week/100</td>
<td></td>
<td>0.0986 (0.0271)***</td>
<td>7.30 (3.02,17.68)****</td>
</tr>
<tr>
<td>Physical activity score/100</td>
<td></td>
<td>–0.0736 (0.0342)*</td>
<td>0.12 (0.05,0.32)****</td>
</tr>
<tr>
<td>Average daily energy intake (kcal)/100</td>
<td></td>
<td>0.0028 (0.0008)***</td>
<td>0.76 (0.62,0.92)**</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index; TV, television. aFor the BMI-for-age z-score model, the cells show estimated model coefficients, s.e. in parentheses, and P-values indicated by asterisks. bFor the model of overweight, the cells show odds ratios, 95% confidence interval in parentheses, and P-values indicated by asterisks. The interaction odds ratio (days with 3+ meals × Race) is interpreted as the ratio of odds ratios for the estimated meal frequency effects for black and white girls. Specifically, for black girls, the estimated odds ratio for days with 3+ meals was 0.8125 (meaning that for each additional day consuming 3+ meals, black girls were 0.81 times as likely to be overweight, or conversely they were 1/0.81 times as likely to be underweight). While for white girls the odds ratio was 1.0197; 0.8125 divided by 1.0197 yields the odds ratio shown in the table, 0.80. *P < 0.05 **P < 0.01 ***P < 0.001 ****P < 0.0001.

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