

Meal Frequency and Childhood Obesity

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Abstract

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Objective: Previous studies have demonstrated an inverse association between meal frequency and the prevalence of obesity in adulthood. The aim of this study was to assess the relationship between meal frequency and childhood obesity.

Research Methods and Procedures: Stature and weight of 4370 German children ages 5 to 6 years were determined in six Bavarian (Germany) public health offices during the obligatory school entry health examination in 2001/2002. An extensive questionnaire on risk factors for obesity was answered by their parents. Obesity was defined according to sex- and age-specific BMI cut-off points proposed by the International Obesity Task Force. The main exposure was daily meal frequency.

Results: The prevalence of obesity decreased by number of daily meals: three or fewer meals, 4.2% [95% confidence interval (CI), 2.8 to 6.1]; four meals, 2.8% (95% CI, 2.1 to 3.7); and 5 or more meals, 1.7% (95% CI, 1.2 to 2.4). These effects could not be explained by confounding due to a wide range of constitutional, sociodemographic, and lifestyle factors. The adjusted odds ratios for obesity were 0.73 (95% CI, 0.44 to 1.21) for four meals and 0.51 (95% CI, 0.29 to 0.89) for five or more meals. Additional analyses pointed to a higher energy intake in nibblers compared with gorgers.

Discussion: A protective effect of an increased daily meal frequency on obesity in children was observed and appeared to be independent of other risk factors for childhood obesity. A modulation of the response of hormones such as insulin might be instrumental.

Key words: epidemiology, diet, prevention and control, energy metabolism, feeding behavior

Introduction

Overweight and obesity are the most common nutritional disorders in industrialized countries, and they continue to increase in their prevalences (1–3). Childhood obesity predicts obesity in adulthood (4–6) and later cardiovascular disease (7–9). Effective prevention strategies against childhood obesity are needed because therapeutic interventions are expensive and tend to have poor long-term results (3,10).

Previous studies have demonstrated an inverse association between meal frequency and the prevalence of overweight and obesity in adults (11–14). In other studies, the failure to find a significant protective effect among adults might possibly have been due to lack of sample power (15–17). Differences in the ascertainment and definitions of meals across studies, e.g., total number of meals per day (11–14) vs. predefined meal periods (15–17), might have further contributed to the heterogeneity of the findings.

To our knowledge, the association between meal frequency and body weight in children has been addressed in only three studies, one study including 226 children 6 to 16 years (18) and two recent studies including 1562 children (19) and 1584 children (20). The failure to detect a significant association between meal frequency and the prevalence of overweight in these studies was possibly due to lack of sample power (18–20). Thus, the predictive potential of an increased habitual meal frequency in younger children remains unknown.

To assess the impact of increased meal frequency on overweight and obesity among apparently healthy preschool children, we analyzed data from a cross-sectional survey performed as part of the 2001/2002 Bavarian school entry health examination with an extensive questionnaire on a wide range of sociodemographic and lifestyle factors possibly related to overweight and obesity in children.

Research Methods and Procedures

Study Population and Data Sources

Children in the year before school entry have to attend a mandatory school entry health examination in local public

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health offices. The purpose of this compulsory examination is to assess deficits that might influence school performance (e.g., impaired visual faculty) but can easily be corrected (e.g., prescription of glasses). Most of the children are at age 5 or 6 when examined. Parents of 8741 children were invited to participate in a voluntary self-completion questionnaire study as part of their child's obligatory school entry examination in six Bavarian (Germany) communities from September 2001 to August 2002. Questionnaires were mailed together with the invitations for the school entry health examination. Approximately 80% ($n = 7026$) completed questionnaires were returned. Data on a number of sociodemographic and potential risk factors for childhood obesity were linked with children's stature and weight measures. The study was approved by the Bavarian State Office for Data Protection.

The analysis was confined to children with German nationality (477 exclusions), at least 5 years but <7 years of age (88 exclusions). Further inclusion criteria were full information on anthropometric measures (293 exclusions), meal frequency (168 exclusions), and potential confounding factors (1630 exclusions). After exclusions, data for 2070 girls and 2300 boys (total $n = 4370$) were available for analysis.

Measures

Stature and weight were measured in light clothing and without shoes by trained nurses of respective public health offices. Stadiometers and balances are periodically calibrated by respective gauging offices. Overweight and obesity were defined according to sex- and age-specific BMI cut-off points proposed by the International Obesity Task Force (21), which are equivalent to the widely used cut-off points of 25 and 30 kg/m² for adult overweight and obesity.

The parental questionnaire was self-administered. The question on child's daily frequency of meals was: How many meals per day does your child consume? Possible answers were 1/2/3/4/5/>5 and do not know. To define a meal, examples were given (i.e., breakfast, lunch, tea, dinner). These examples represent meals, which are conventionally served on a plate.

The following variables were a priori considered as potential confounding factors for the association between main meal frequency and childhood obesity due to their reported or possible associations with childhood overweight/obesity: parental education, highest level attained by either parent, ordinal in five levels (self-reported by parents) (22); parental obesity, metric self-reporting, height in centimeters and weight in 0.1-kg steps (23,24); watching television or playing video games, daily hours at school entry (self-reported by parents) (25,26); physical activity at school entry, reported by parents according to the Child Behavior Checklist in four categories (27); breastfeeding, in categories of none,

up to 1 month, and >1 month (28); eating snacks while watching television, ordinal, frequency five weekday categories (self-reported by parents) (29); having main meals alone, ordinal, frequency five weekday categories (self-reported by parents); child's consumption of instant food, frequency five weekday categories (self-reported by parents); and smoking in pregnancy (30–32). Additional analyses considered information from a food frequency questionnaire based on a standard food frequency questionnaire for children, which was used in a national study (33). Nutrient intake was calculated based on a standard German nutrient table (34).

Statistical Analysis

The prevalence of overweight/obesity and 95% exact confidence limits associated with meal frequency were calculated based on the binomial distribution (35). Dose-response effects were estimated with the Cochran-Armitage test for trend ($p < 0.05$). Crude and adjusted odds ratios (ORs)¹ and their respective 95% confidence limits for maternal smoking and overweight/obesity were calculated using logistic regression analysis. All covariates associated both with meal frequency and overweight/obesity ($p < 0.2$) (36) were considered as potential confounders. Multicollinearity of respective covariates was identified by a variance inflation factor > 2.5 (37). A number of possible interactions (parental education, child's sex, parental obesity, breastfeeding) with meal frequency and their influence on offspring's obesity were considered. All potential confounding and independent risk factors ($p < 0.05$) were included in multiple logistic regression analysis. The potential confounders had been dichotomized for the sake of better comprehensibility. To assess residual confounding as a result of dichotomization, covariates were additionally modeled in their ordinal or continuous forms or were coded using binary dummy variables (breastfeeding) as appropriate (38). Forward selection was used to generate the final logistic regression model and was based on the deviance as goodness of fit measure. To avoid confusion, we did not present so-called pseudo- R^2 values, which in logistic models do not describe the variance explained by the model, unlike the R^2 values in linear models.

All calculations were carried out with the software package SAS version 8.2 (SAS Institute Inc., Cary, NC).

Results

The number of children consuming four meals per day was 1896 children (43.4%), whereas 1706 children (39.0%) consumed five daily meals. The proportion of children consuming more than five daily meals was only 2.9%,

¹ Nonstandard abbreviations: OR, odds ratio; CI, confidence interval.

Table 1. Number of daily meals and prevalence (95% CI) of overweight and obesity among German preschool children

Meal frequency per day	% Overweight (95% CI)*	% Obesity (95% CI)*
Three or fewer (<i>n</i> = 641)	15.0 (12.3 to 18.0)	4.2 (2.8 to 6.1)
Four (<i>n</i> = 1896)	10.9 (9.5 to 12.4)	2.8 (2.1 to 3.7)
Five or more (<i>n</i> = 1833)	8.1 (6.9 to 9.4)	1.7 (1.2 to 2.4)
Overall (<i>n</i> = 4370)	10.3 (9.4 to 11.3)	2.6 (2.1 to 3.1)

* Cochran-Armitage Trend Test, $p < 0.001$.

whereas 14.7% of the children had only three daily meals at maximum.

The prevalence of overweight and obesity decreased by number of meals per day (Table 1). A dose-response effect with respect to the numbers of meals consumed could be observed.

To identify potential confounders, we assessed the associations between meal frequency and other explanatory variables and between explanatory variables and overweight/obesity (Table 2). Frequent daily meals were associated with a high educational level, decreased prevalence of having main meals alone, daily television watching no

Table 2. Description of study sample (*n* = 4370); prevalences of overweight and obesity with respect to explanatory variables

Covariate (no. of exposed subjects to covariate)	Prevalence			
	Overweight (%)		Obesity (%)	
	Exposed to covariate	Non-exposed to covariate	Exposed to covariate	Non-exposed to covariate
Parental education (≥ 10 school years)* (<i>n</i> = 3207)	9.1	13.5	2.0	3.8
Parental obesity (either parent BMI ≥ 30 kg/m ²)* (<i>n</i> = 594)	22.1	8.5	8.6	1.6
Male sex (<i>n</i> = 2300)	9.3	11.5	2.1	3.0
Having at least 1 main meal/wk alone (<i>n</i> = 185)	15.1	10.1	4.3	2.5
Daily watching television > 1 hour* (<i>n</i> = 1571)	14.8	7.8	4.7	1.4
Child's consumption of instant food at least once a week (<i>n</i> = 982)	11.2	10.1	3.2	2.4
Breastfed > 1 month* (<i>n</i> = 2637)	8.8	12.7	1.8	3.8
Little physical activity at school entry* (<i>n</i> = 953)	17.1	8.4	5.9	1.6
Having siblings (<i>n</i> = 3568)	9.9	13.0	2.5	2.9
Birth order: first child (<i>n</i> = 1850)	11.4	9.1	2.8	2.3
Smoking in pregnancy* (<i>n</i> = 905)	14.7	9.2	5.0	1.9
Regular snacking while watching television* (<i>n</i> = 1686)	12.0	9.2	3.4	2.0

* Significantly ($p < 0.05$) associated with outcome (overweight and obesity).

Table 3. Results of multiple regression analysis including main exposure and confirmed confounders (associated with both meal frequency and childhood overweight/obesity)

Explanatory variable	OR for meal frequency (95% CI)			
	Overweight		Obesity	
	Crude	Adjusted	Crude	Adjusted
Four daily meals*	0.70 (0.54 to 0.90)	0.73 (0.56 to 0.96)	0.67 (0.42 to 1.07)	0.73 (0.44 to 1.21)
Five or more daily meals*	0.50 (0.38 to 0.66)	0.56 (0.42 to 0.75)	0.39 (0.23 to 0.66)	0.51 (0.29 to 0.89)
Parental education (≥ 10 school years)	0.65 (0.53 to 0.80)	0.85 (0.68 to 1.06)	0.51 (0.34 to 0.75)	0.82 (0.54 to 1.25)
Parental obesity (either parent BMI ≥ 30 kg/m ²)	3.06 (2.44 to 3.83)	2.65 (2.09 to 3.35)	5.72 (3.90 to 8.39)	4.40 (2.93 to 6.60)
Daily watching television > 1 hour	2.04 (1.68 to 2.48)	1.63 (1.31 to 2.03)	3.45 (2.33 to 5.11)	2.34 (1.50 to 3.65)
Breastfed > 1 month	0.66 (0.54 to 0.80)	0.85 (0.69 to 1.06)	0.47 (0.32 to 0.68)	0.73 (0.48 to 1.11)
Little physical activity at school entry	2.24 (1.82 to 2.76)	2.05 (1.66 to 2.55)	3.75 (2.57 to 5.47)	3.11 (2.10 to 4.63)
Smoking in pregnancy	1.70 (1.37 to 2.12)	1.38 (1.10 to 1.74)	2.65 (1.81 to 3.90)	1.86 (1.22 to 2.84)
Regular snacking while watching television	1.34 (1.10 to 1.64)	0.94 (0.75 to 1.17)	1.74 (1.19 to 2.53)	0.93 (0.61 to 1.43)

* Three or fewer daily meals as reference group.

more than 1 hour, no regular snacking in front of the television, having siblings, non-smoking in pregnancy, and breastfeeding more than 1 month (data not shown).

Obesity at school entry was most strongly associated with parental obesity, followed by little physical activity, watching television, smoking in pregnancy, and snacking in front of the television. Breastfeeding was inversely related to obesity, followed by high parental education (Table 2). None of the interaction terms (parental education, child's sex, parental obesity, or breastfeeding with meal frequency) was significantly associated with overweight/obesity.

A higher meal frequency reduced the crude OR for child's overweight and obesity with a clear dose-response effect (Table 3). Adjustment for parental education, parental obesity, watching television, breastfeeding, little physical activity, smoking in pregnancy, and snacking in front of the television could not explain the effect of meal frequency on overweight/obesity (Table 3).

The adjusted ORs for four daily meals/five or more daily meals with ordinal or continuous covariates were 0.75 [95% confidence interval (CI), 0.57 to 0.99]/0.58 (95% CI, 0.44 to 0.77) for overweight and 0.76 (95% CI, 0.46 to 1.24)/0.52 (95% CI, 0.30 to 0.90) for obesity, which were similar to the figures based on dichotomous covariates presented in Table 3. The highest variance inflation factor (1.3 for snacking in

front of the television) was clearly lower than 2.5, suggesting absence of multicollinearity.

Coding meal frequency as a metric variable in the same final regression model resulted in an OR of 0.80 (95% CI, 0.70 to 0.91) for overweight and 0.68 (95% CI, 0.53 to 0.86) for obesity per additional daily meal. Stratification by sex did not change the results (data not shown).

Additional analyses regarded the food intake related to the frequency of meals. Increasing number of daily meals was associated with a higher daily caloric (64.8 kcal/additional meal), fat (3.4 g/per additional meal), protein (0.6 g/per additional meal), and carbohydrate (9.7 g/per additional meal) intake. Although no differences among intake of bread rolls and lemonade were observed, nibblers consumed fewer potatoes (boiled, fried, chips), pastries, candy bars, chocolate, and cola, but more pasta, fresh salads, fresh fruits, and fresh vegetables (Cochran-Armitage trend test, $p < 0.05$).

Discussion

The primary objective of the study was to assess the potential role of an established strategy for obese children to prevent adulthood obesity. An increased meal frequency was inversely related to the prevalence of childhood over-

weight and obesity, suggesting that frequent meals might be protective. This finding requires confirmation in future studies.

Our results on meal frequency and overweight/obesity are consistent with similar studies among adults (11–14,18,39). The findings of two recent studies in children, which failed to detect a significant association between meal frequency and childhood obesity (19,20), are not contradictory to our observations. Different findings may be explained by differences in children's age, ascertainment/definitions of meals, definition of overweight/obesity, and lack of power in these studies. However, the direction and size of the effect in the Bogalusa Heart Study enrolling 1584 children (20) was similar to our study: OR of 0.8 for childhood overweight and eating at least three meals compared with eating fewer than three meals. This OR fell short of being significant due to lack of sample power. A sample size of at least ~2800 children would have been necessary to detect an effect of this size and in this setting (assumptions: estimated overweight prevalence = 11%, α = 5%, power = 80%). Similarly, in the U.S. study, enrolling 1562 children and yielding a pooled OR of 0.9 (19), lack of power may explain the failure to detect a significant association. The study of 226 children, which reported no point estimate of the effect for children ≤ 10 years of age, was even more underpowered (18).

Regarding other risk/protective factors for obesity, our results also fit into known patterns; as in other studies, poor educational level (22,40), parental obesity (23,24), and watching television (25,26) were associated with childhood obesity, whereas physical activity (27,41) and breastfeeding were protective (28,42–44).

A wide range of potential confounding factors could not explain the association between the number of meals and the prevalence of overweight and obesity. Thus, increasing meal frequency could possibly be a target for early prevention of overweight/obesity in children. Several methodological constraints of the data have to be considered.

Methodological Considerations

This is a cross-sectional study. As with all cross-sectional studies, reverse causality may be an important issue (45). Similar effects, however, have been found in randomized trials among young college students and adults (18,39) and in prospective experimental animal studies (46). A single dietary recall might not be adequate to characterize the usual eating patterns or meal frequency of an individual, but it is sufficient for characterizing the eating patterns or meal frequency of large groups of children (19).

Reporting bias is another important issue. Underreporting of food intake (47,48), especially snacks (48–50) or carbohydrates (49), among obese participants could result in a spurious association between meal frequency and obesity. Underreporting or socially accepted answers cannot be

ruled out for our data. Because parents of gorgers reported higher consumptions of foods with an unhealthy image, such as fried potatoes and chips, however, accurate answers regarding food selection habits may be assumed.

Analysis of cases with complete information only could result in selection bias. To control for a possible selection bias, crude ORs of meal frequency and childhood overweight/obesity were compared between the entire sample with information on anthropometric measures and meal frequency ($n = 6255$) and the restricted sample with information on anthropometric measures and all covariates. The crude ORs for overweight were similar for the entire sample with 0.77 (95% CI, 0.63 to 0.93) for four daily meals and 0.51 (95% CI, 0.41 to 0.63) for five or more daily meals compared with the restricted sample with 0.70 (0.54 to 0.90) for four daily meals and 0.50 (95% CI, 0.38 to 0.66) for five or more daily meals. Therefore, a selection bias due to complete case analysis seems to be unlikely.

Additionally, the return rate of the questionnaires was high with 80.4%. This is well above the 66% in other nationwide surveys (51), suggesting that valid analyses are possible.

A surprising finding was the higher nutrient and energy intake in nibblers. This appears paradoxical at first sight but is consistent with the results of other studies observing a lower caloric and fat intake among adults with lower meal frequencies (11,12,14). This finding indirectly supports the validity of the self-reported question on meal frequency.

Possible Biological Mechanisms

An increased daily overall thermogenesis after consumption of more meals could be a potential explanation. However, there is an ongoing controversy regarding the role of this mechanism because studies on thermic food effects did not observe different thermogenesis between nibbling vs. gorging regimens (45). In addition, no difference in total energy expenditure was observed between gorging and nibbling obese adults in a chamber calorimeter study (52).

Another mechanism potentially affecting the role of energy expenditure could be differing levels of physical activity between nibblers and gorgers. An association between meal frequency and habitual levels of physical activity seems to be unlikely because parents' reports on general physical activity at school entry were not associated with daily meal frequency in our data.

A further possible mechanism might be the association between the number of meals consumed and insulin metabolism. In a randomized crossover study among healthy men, lower postprandial insulin concentrations accompanied by lower serum lipid levels were observed after the nibbling regimen (39,53). Additionally, an animal study reported markedly higher postprandial triacylglycerol and cholesterol ester levels in gorging animals compared with nibbling ones (46). Insulin is known to stimulate lipogenesis in

arterial tissues and enhances the growth and proliferation of arterial smooth muscle cells (39,53). The increased triglyceride synthesis in adipose tissue triggered by higher postprandial glucose and insulin levels (39,53) might contribute to the higher prevalence of obesity among gorgers. This concept is further supported by a study among boxers. In a food restriction trial, one-half of the boxers consumed two daily meals (600 kcal each), and the other one-half consumed six daily meals (200 kcal each) (54). Both groups showed a similar amount of weight loss, but boxers eating 600 kcal twice daily lost more muscle and less fat than those eating 200 kcal six times daily (54). Although infrequent consumption of huge meals appears to favor fat deposition, frequent consumption of small servings adding up to the same total caloric intake does not. Infrequent consumption patterns might have been useful in times with limited food resources, as pointed out by Fabry (11), whereas during times of abundance of food, such eating habits might constitute a risk factor for obesity.

The observed association of an increased daily meal frequency and childhood overweight/obesity underlines the importance of food intake patterns in childhood. Skipping meals might not be an appropriate approach for reducing the risk of obesity in children. Prospective preventive trials to confirm the protective potential of frequent meals for childhood overweight and obesity might be worthwhile.

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