Eating Frequency and Overweight and Obesity in Children and Adolescents: A Meta-analysis

OBJECTIVES: To determine the effect of eating frequency on body weight status in children and adolescents.

METHODS: In this meta-analysis, original observational studies published to October 2011 were selected through a literature search in the PubMed database. The reference list of the retrieved articles was also used to identify relevant articles; researchers were contacted when needed. Selected studies were published in English, and they reported on the effect of eating frequency on overweight/obesity in children and adolescents. Pooled effect sizes were calculated using a random effects model.

RESULTS: Ten cross-sectional studies and 1 case-control study (21 substudies in total), comprising 18,849 participants (aged 2–19 years), were included in the analysis. Their combined effect revealed that the highest category of eating frequency, as compared with the lowest, was associated with a beneficial effect regarding body weight status in children and adolescents (odds ratio [OR] = 0.78, log OR = −0.24, 95% confidence interval [CI] −0.41 to −0.06). The observed beneficial effect remained significant in boys (OR = 0.76, log OR = −0.27, 95% CI −0.47 to −0.06), but not in girls (OR = 0.96, log OR = −0.04, 95% CI −0.40 to 0.32) (P for sex differences = 0.14).

CONCLUSIONS: Higher eating frequency was associated with lower body weight status in children and adolescents, mainly in boys. Clinical trials are warranted to confirm this inverse association, evaluate its clinical applicability, and support a public health recommendation; more studies are also needed to further investigate any sex-related differences, and most importantly, the biological mechanisms.
The rates of childhood obesity have risen to an alarming level over the past 3 decades. Evidence so far attributes this phenomenon to the interplay between genetic and environmental factors. As far as diet is concerned, total energy, macronutrients, and food group intake have long been investigated. However, the existing dietary etiological models cannot fully explain the development and maintenance of child- hood obesity: research needs to move beyond specific nutrients and foods and focus on dietary patterns and eating behaviors, including eating frequency. Most studies in adults suggest that greater eating frequency is associated with a healthier weight status. Fabry and colleagues, in the 1960s, were the first to explore this effect in children. They performed an interventional study on 226 children, aged 6 to 16, and found that children who were provided 3 meals per day had an increased tendency to deposit fat, compared with those who were given 7 or 5 meals per day in smaller portions. Interestingly, these differences were found in older (10–16 years), but not younger children (boys: 6–11 years and girls: 6–10 years), and were more obvious in girls compared with boys. The authors speculated that the hormonal changes during puberty may mediate the effect of eating frequency on body weight. Since then, numerous epidemiologic studies have been conducted to explore the potential relationship between the total number of eating events or the number of meals and snacks and obesity risk in children and adolescents. However, the effect, if any, still remains unclear, as well as the potential underlying mechanisms. Kirk proposed that there are 4 possible physiologic advantages associated with frequent eating that may improve body-weight control: frequent eating may help people to regulate appetite and daily energy compensation, to increase the carbohydrate-to-fat ratio of the diet, to shift the temporal distribution of energy intake toward earlier parts of day and to keep a more physically active lifestyle.

The research question addressed here was to evaluate at what extent eating frequency is associated with body weight status (overweight/obesity), in children and adolescents, through a meta-analysis of the existing findings of published original observational studies. As there is no scientific consensus on the most appropriate definition to categorize the different eating occasions (ie, meals versus snacks), total eating frequency was evaluated.

METHODS

Search Strategy

Original research, observational studies published until October 2011, examining the association between eating frequency and overweight/obesity status in children and adolescents, were selected through a literature search in the PubMed database. Specific key words were used for this search: “eating frequency,” “meal frequency,” “meals,” and “eating episodes,” in combination with the term “overweight” or “obesity.” In addition, the reference list of the retrieved and eligible articles was used to identify relevant articles that were not extracted through the searching procedure. The initial search resulted in 1069 entries in PubMed on eating frequency and obesity/overweight, 155 entries on meal frequency and overweight/obesity, 414 entries on meals and overweight/obesity, and 69 entries on eating episodes and overweight/obesity.

Study Selection

The relevance of studies was assessed by using a hierarchical approach based on title, abstract, and full manuscript. Studies eligible for inclusion were those published in English. All of the selected studies were conducted in children and/or adolescents (2–19 years old), and provided results in a form that could be used for the present analysis (point estimates of odds ratio [OR] with 95% confidence intervals [CIs] or SEs available or derivable). The selected studies were cross-sectional, apart from 1 case-control. In the present meta-analysis, the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines were followed.

Data Extraction

The following study characteristics were extracted from the original reports by using a standardized data extraction form and included in the meta-analysis: name of the study (if there was a specific one), lead author, year of publication, country of origin, sample size, mean age and sex of participants, effect size measurements (OR), and variables that entered into the multivariable model as potential confounding factors. This information was also extracted: 95% CIs, the number of daily meals/eating episodes used as reference category, the method used to evaluate eating frequency, the definition of a meal/eating episode, and the definition criteria for overweight/obesity in children and adolescents. In some cases, additional information or data were requested from the authors; 4 authors were contacted, but only 3 of them responded to our request. One investigator (P.K.) collected the relevant articles; 2 authors reviewed the literature (P.K. and M.Y.) independently and disagreements were solved by consensus and by the opinion of the third author (D.B.P.). Quality of studies was not assessed because the total number of studies was limited.

Statistical Analysis

Results of the individual studies are presented as ORs and their corresponding
95% CIs. Data were collected from the most adjusted model. To calculate the combined effect of the selected studies, a random effects meta-analysis was applied. Each study was represented by a dummy variable, and the use of a random effects model was possible because SEs of the point estimates within studies were provided by the investigators. With regard to the analysis for overweight/obesity, each data point consisted of the number of meals/eating episodes consumed daily and the OR of being overweight/obese. The combined effect size measures derived from the meta-analysis are presented as ORs, log ORs, and their 95% CIs. Heterogeneity that was attributed to studies rather than to chance was assessed by using Cochran’s Q and I² (I² ranges between 0% and 100%, with lower values representing less heterogeneity) and evaluated by using the χ² test. To assess the presence of publication bias, the “funnel’s plot” was created, and tested with the Egger linear regression method of asymmetry (test of the intercept). All statistical calculations were performed in NCSS/PASS 2005 software (Number Cruncher Statistical Systems Co, Kaysville, UT).

RESULTS

Study Selection

Figure 1 shows results from the literature search and study-selection process. Overall, 11 studies were finally included in this meta-analysis, after screening 1707 titles and abstracts and reviewing 30 full articles. A manual search of references cited in these articles did not yield new eligible articles. Among these 11 studies, some studies presented their results according to participants’ sex,14,15,21–23 ethnic origin,14 and age group.22 Moreover, the report of Toschke et al16 included separate results of OR for overweight and for obesity. Therefore, 21 substudies of the initial 11 original studies were included in the meta-analysis.

Study Characteristics

Study characteristics are presented in Tables 1 and 2. The overall working sample consisted of 18 849 subjects, aged 2 to 19 years. Sample sizes of the 21 substudies varied between 265 and 4370 participants. With regard to the geographical distribution of the studies, 8 were conducted in Mediterranean populations (Greece, Portugal, Italy, and Turkey), 2 in North American–North European populations (United States and Germany), and 1 in a Latin American population (Brazil). No race-related differences of the participants were reported, with the exception of the Bogalusa Heart Study; in this case, the study population consisted of 1562 children, aged 10 years, with a biracial background (65% European American, 35% African American). In most studies, participants were categorized as overweight/obese according to International Obesity Task Force BMI cutoff points.24 However, other criteria were also used: the reference standards of the Centers for Disease Control and Prevention,25 and the Greek growth charts developed by the First Department of Pediatrics of Athens University Medical School.26

As it was revealed from the studies’ methodology section, the evaluation of eating frequency was mainly based on self-reported questionnaires completed by children (aged 10–19 years) themselves,15,23,27,28 or by their caregivers/parents.16,19,21,29–31 However, in 2 studies,14,22 information from the 24-hour dietary recalls was used. There are also differences between studies in the definition used for a meal or an eating episode. For example, in the study of Turkkahraman et al,20 the total number of daily meals consumed referred to the number of meals considered as “formal” eating events, and, thus, snacks were excluded from analysis, whereas in the study of Kontogianni et al,22 any eating or drinking occasion separated by at least 15 minutes from other events during the day was defined as an eating episode, accounting for the total daily number of eating episodes.
<table>
<thead>
<tr>
<th>Reference/ Name of the Study</th>
<th>Country, Year</th>
<th>Sample, n</th>
<th>Type of Study</th>
<th>Evaluation of Eating Frequency</th>
<th>Parameters Evaluated</th>
<th>Overweight/Obesity Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicklas et al\textsuperscript{14} (The Bogalusa Heart Study)</td>
<td>US, 2003</td>
<td>513 EA/279 AA, 497 EA/273 AA</td>
<td>10 Cross-sectional</td>
<td>One 24-h dietary recall</td>
<td>Dietary intake, Age</td>
<td>Age- and sex specific CDC reference standards: At risk for overweight: BMI ≥ 85th percentile; overweight: BMI ≥ 95th percentile</td>
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<td>Note: Children at risk for overweight and overweight were combined to reflect the overweight group</td>
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<tr>
<td>Toschke et al\textsuperscript{16}</td>
<td>Germany, 2005</td>
<td>2070 2300</td>
<td>5–7 Cross-sectional</td>
<td>Parental questionnaire (possible answers: 1/2/3/4/5/6 and don't know)</td>
<td>Year participating in the Study</td>
<td>Sex- and age-specific cutoff points proposed by IOTF</td>
</tr>
<tr>
<td>Neutzling et al\textsuperscript{27}</td>
<td>Brazil, 2003</td>
<td>508</td>
<td>Case-control</td>
<td>Standardized and precoded questionnaire — self-reported (Number of daily meals)</td>
<td>Age, Frequency and amount of physical activity, Hours of sleep, Hours of watching television, playing video games, and using a computer per day, Dietary habits, Number of daily meals, Sex, maturity, Smoking, Dieting for weight-loss reasons, Socioeconomic status, Total breastfeeding duration, Birth wt, Wt, height, BMI, and Schooling of Parents</td>
<td>Not specified</td>
</tr>
<tr>
<td>Barba et al\textsuperscript{19} (ARCA project)</td>
<td>Italy, 2006</td>
<td>3668</td>
<td>6–11 Cross-sectional</td>
<td>Parental questionnaire (Yes or No)</td>
<td>Body wt, height, waist circumference and BP, Parental clinical history, demographics and lifestyle</td>
<td>Sex- and age-specific cutoff points proposed by IOTF</td>
</tr>
<tr>
<td>Turkkahraman et al\textsuperscript{29}</td>
<td>Turkey, 2008</td>
<td>2465</td>
<td>6–17 Cross-sectional</td>
<td>Parental questionnaire</td>
<td>Demographic variables, Birth wt</td>
<td></td>
</tr>
<tr>
<td>Reference/ Name of the Study</td>
<td>Country, Year</td>
<td>Sample, n</td>
<td>Type of Study</td>
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<tr>
<td>Kosti et al²³ (The Vyronas study)</td>
<td>Greece, 2007</td>
<td>987 1021</td>
<td>Cross-sectional</td>
<td>Semi-quantitative Food Frequency Questionnaire</td>
<td>Body wt, height, Dietary habits, Physical activities, Sedentary activities (watching television, working on a computer, playing video games)</td>
<td>Sex- and age-specific cut off points proposed by IOTF</td>
</tr>
<tr>
<td>Ferreira &amp; Marquez-Vidal²¹</td>
<td>Portugal, 2008</td>
<td>544 581</td>
<td>Cross-sectional</td>
<td>Parental questionnaire (mean number of meals consumed)</td>
<td>Body wt, height, upper arm, waist circumference, Triceps skinfold, Birth wt, Duration of breast-feeding, Dietary habits, Parents’ wt, height</td>
<td>Sex- and age-specific cutoff points proposed by IOTF</td>
</tr>
<tr>
<td>Lagiou &amp; Parava²²</td>
<td>Greece, 2008</td>
<td>633</td>
<td>Cross-sectional</td>
<td>Interviewer-administered questionnaire (number of eating occasions)</td>
<td>Sociodemographic variables, Birth order, Paternal education, Dietary patterns, Energy intake, Physical activity, Sedentary activities (watching television, working on a computer, playing video games), Triceps skinfold, Birth wt, Duration of breast-feeding, Dietary habits, Parents’ wt, height</td>
<td>Greek growth charts developed by the First Department of Pediatrics of Athens University Medical School</td>
</tr>
<tr>
<td>Kontogianni et al²²</td>
<td>Greece, 2010</td>
<td>344 346</td>
<td>Cross-sectional</td>
<td>One 24-h dietary recall (total eating episodes per day; any eating/drinking occasion separated by at least 15 min from other events)</td>
<td>Sociodemographic variables, Parental education, Dietary intake, Eating behaviors, Adherence to the Mediterranean diet guidelines, Energy intake/ BMR: for the assessment of low energy reporting, Physical activity, Sedentary activities (watching television, working on a computer, playing video games)</td>
<td>Sex- and age-specific cutoff points proposed by IOTF</td>
</tr>
<tr>
<td>Cassimos et al²¹</td>
<td>Greece, 2011</td>
<td>335</td>
<td>Cross-sectional</td>
<td>Questionnaire completed by parents</td>
<td>Body wt, height, Blood pressure, Parents’ wt, height, Socioeconomic status, Parents’ educational status, Dietary habits, Time sleeping and time watching television of the children</td>
<td>Sex- and age-specific cutoff points proposed by IOTF</td>
</tr>
</tbody>
</table>

AA, African American; BMR, basal metabolic rate; BP, blood pressure; CDC, Centers for Disease Control and Prevention; EA, European American; IOTF, International Obesity Task Force; wt, weight.
Eating Frequency and Overweight/Obesity Status in Children and Adolescents

Figure 2 summarizes the effect of eating frequency on overweight/obesity status in children and adolescents. Overall, increased eating frequency, as compared with the lowest category, was associated with 0.78-times lower odds (ie, log OR = −0.24, 95% CI −0.41 to −0.06), which means 22% lower likelihood of being overweight/obese. A significant heterogeneity of the effect sizes of the number of meals on overweight/obesity was observed (Q = 41.63, P = .003, I² = 51.9%). Moreover, an asymmetric plot of the ORs versus SE (lnOR) was then constructed (not presented here), indicating potential presence of publication bias, as smaller studies showing no beneficial effects on overweight/obesity were missing. However, the Egger method of asymmetry clearly suggested no publication bias.
bias (b0 = 1.29, 95% CI −2.1 to 4.6, \( P_{\text{one-tailed}} = .21 \)).

### Sensitivity Analysis

When stratified by sex, the observed beneficial effect remained significant in boys (\( n = 3408, \text{OR} = 0.76, \log \text{OR} = −0.27, 95\% \text{CI} −0.47 \) to −0.06), but not in girls (\( n = 3462, \text{OR} = 0.96, \log \text{OR} = −0.04, 95\% \text{CI} −0.40 \) to −0.32) (Fig 3) (\( P \) for sex differences = 0.14). The a-posterior statistical power was 95% for the subanalysis in boys and 19% for the subanalysis in girls. No significant heterogeneity of the effect measures regarding overweight/obesity in boys was observed (Q = 7.78, \( P = .35, I^2 = 10.0\% \)). However, heterogeneity of the effect sizes of the number of meals on overweight/obesity was observed in girls (Q = 17.46, \( P = .008, I^2 = 65.6\% \)). Then, a subgroup analysis was performed according to the tool used to measure eating frequency. Based on the studies that evaluated eating frequency by using precoded, self-reported questionnaires, the number of meals/eating episodes was still inversely associated with overweight/obesity (\( \text{OR} = 0.77, \log \text{OR} = −0.26, 95\% \text{CI} −0.49 \) to −0.04); whereas, in the 2 studies that used 24-hour recalls, the number of meals/eating episodes was not associated with the outcome (\( \text{OR} = 0.84, \log \text{OR} = −0.17, 95\% \text{CI} −0.45 \) to 0.11). Heterogeneity of the effect sizes was observed in the subanalysis that evaluated data only from the questionnaires (Q = 30.71, \( P = .006, I^2 = 54.4\% \)), but not in the subanalysis that evaluated information from recalls (Q = 9.71, \( P = .08, I^2 = 48.5\% \)). No attempt was made to perform a subgroup analysis by age group, as there were only 2 studies in adolescents (Table 1).

Finally, the impact of the selected studies on the combined effect was tested, by removing each study and recalculating the combined effect and the corresponding log-transformed 95% CI of the remaining studies. The combined effect sizes under each scenario of the study's removal remained unaltered (the 95% CIs varied within −0.45 to −0.01).

### DISCUSSION

#### Summary and Interpretation of Findings

To the best of our knowledge, this is the first work that has systematically assessed the association between eating frequency and overweight/obesity in children and adolescents. The presented meta-analysis of 21 substudies, with an overall incorporated population of 18 849 subjects, revealed an inverse association between eating frequency (i.e., the total number of meals/eating episodes consumed on a daily basis) and overweight/obesity status in children and adolescents. Specifically, children and adolescents who had a higher number of eating episodes per day had 22% lower probabilities of being overweight or obese compared with those who had fewer episodes. Interestingly, the inverse association was evident only in boys and not in girls, suggesting that there are sex related differences in dietary patterns and behaviors and their effect on overweight/obesity. However, at this point it should be noted that the presence of publication bias, and the significant heterogeneity observed in the results of the selected studies, indicates the need for further investigations in this important scientific field.

Several pathways have been proposed to explain the association between higher eating frequency and lower body weight in children. The obvious effect of thermogenesis that follows food
consumption on total energy expenditure was not supported by laboratory experiments that evaluated differences in thermogenesis rates between nibbling and gorging regimens. In contrast, the beneficial effect of increased eating frequency on insulin metabolism may be a potential biological mechanism, but there are no data in young people. Relevant evidence in adults indicates that increased eating frequency attenuates a series of postprandial metabolic and endocrine responses to dietary intake. The mediating or confounding role of physical activity or the active lifestyle has also been proposed in adults, and it may also apply to children.

Regarding the sex-related differences in the association between eating frequency and overweight/obesity in children and adolescents, the available scientific data are still limited and conflicting. The presented results are in accordance with a previous cross-sectional study in Greek adolescents, showing that the daily frequency of eating episodes was associated with obesity indices in boys, but not in girls. At this point it should be underlined that the subanalysis in girls was underpowered, and a substantial heterogeneity of the effect sizes of the selected studies was evident, leading to the conclusion of serious inconsistencies between studies. Moreover, other studies that attempted to identify possible differences between boys and girls did not report significant results. Additional research is needed to clarify this issue and, most importantly, to propose potential mechanisms that may be responsible for a sex-dependent effect.

Limitations

Certain limitations of this work warrant consideration. Because of the type of studies included in the meta-analysis (ie, only observational studies), no causal relationships can be established. Moreover, the characteristics of the selected studies did not allow the evaluation of the exact effect of age in the observed inverse relationship between eating frequency and overweight/obesity status. Significant heterogeneity was present in the pooled analysis, which introduces a warning about the generalization of the results.

Methodological differences between studies may also raise concerns; the most important difference is the definition used for overweight/obesity in children and adolescents and the way that eating frequency was assessed. In most studies, participants were categorized as overweight and obese according to International Obesity Task Force criteria for BMI. However, other criteria were also used. There are differences between reference standards and the corresponding BMI cutoff points, resulting in differences in overweight/obesity classification of the children. There is also variability in the method of assessment of eating frequency (self-reported questionnaires, by children 10–19 years old or by their caregivers, or 24-hour dietary recalls) and in the respective definition given to the eating frequency. This variability is a common limitation in reviews and meta-analyses evaluating eating habits and behaviors. Several suggestions have been made to define eating events according to the time of day, the amount and/or energy of food, the presence/absence of companions.
the quality of food, or combinations of these factors. Moreover, in some studies, participants decide by themselves whether they eat a meal or a snack, and this was the case in a number of investigations included in the present meta-analysis. Interestingly, the only subgroup of studies in which we found a negative association between eating frequency and overweight/obesity was the 1 study that used self-reported questionnaires; however, there were only 2 studies that used recalls for the evaluation of this information. Confounding factors included in the analysis also varied between studies (Table 2). Finally, some researchers presented OR values for overweight, whereas others for obesity, and others for both overweight and obesity.

CONCLUSIONS AND IMPLICATIONS FOR POLICY, PRACTICE, AND RESEARCH

The results of the present meta-analysis suggest an inverse association between eating frequency and overweight/obesity status in children and adolescents. Sex-related differences emerged when this association was assessed separately in boys and girls, as the effect of eating frequency was evident only in boys. Despite the aforementioned considerations, these results are of considerable importance, as changes in the number of eating episodes consumed may be an intervention goal for prevention or early treatment of overweight and obesity. Schools may play an important role in improving children’s eating preferences and patterns, and in this perspective, integrating smaller, more frequent meals in the school environment may be an effective way to battle childhood obesity. Clinical trials are warranted to confirm this inverse association, evaluate the clinical practice applicability, and support a public health recommendation. Future studies should also evaluate the size and types of meals and snacks in terms of volume, energy content, macronutrient composition, or glycemic index and take this evaluation into account when investigating associations between eating/meal patterns and obesity. Finally, in relation to the sex-related differences observed, additional research is needed to explore these differences and, most importantly, the underlying biological and/or social mechanisms.

REFERENCES

19. Barba G, Troiano E, Russo P, Siani A; ARCA Project Study group. Total fat, fat distribution and blood pressure according to eating frequency in children living in southern...


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