Breakfast Frequency and Quality May Affect Glycemia and Appetite in Adults and Children[1–4]

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Abstract

Observational studies of breakfast frequency in children and adults suggest an inverse (protective) association between the frequency of eating breakfast and the risk for obesity and chronic diseases such as type 2 diabetes. More prospective studies with stronger designs are needed, as are experimental studies on this topic. In addition, above and beyond breakfast frequency, the roles of dietary quality and composition need to be studied in the context of eating or skipping breakfast. Experimental studies are also necessary to rigorously test causality and biological mechanisms. Therefore, we conducted 2 pilot experimental studies to examine some of the effects of breakfast skipping and breakfast composition on blood glucose and appetite in children and adults. Our results suggest that breakfast frequency and quality may be related in causal ways to appetite controls and blood sugar control, supporting the hypothesis that the breakfast meal and its quality may have important causal implications for the risk of obesity and type 2 diabetes. J. Nutr. 141: 163S–168S, 2011.

Introduction

Scientists continue to struggle to understand the etiology of obesity and attempts to prevent obesity at the individual or population level have been largely futile. One area of research that may have broad public health applications in obesity prevention is the role of breakfast habits in terms of the frequency and quality of the meal. Breakfast skipping has a high prevalence, with 12–34% of youth regularly skipping breakfast (1–6). A working definition of breakfast for research has been proposed as "the first meal of the day, eaten before or at the start of daily activities (e.g. errands, travel, work), within 2 hours of waking, typically no later than 10:00 in the morning, and of an energy level between 20 and 35% of total daily energy needs." (7) Throughout this article, we refer to breakfast frequency, which is defined as the number of days per week consuming a breakfast meal, with a maximum value set at 7 d so that multiple breakfasts on a single day would only be counted once for that day.

The purpose of this paper is to describe 2 new experimental pilot studies of the possible effects of breakfast frequency and quality on appetite and blood sugar in adults and children. Two recent review articles have described the physiological mechanisms that may explain why meal skipping, and breakfast skipping in particular, may lead to upregulation of appetite, possibly leading to weight gain over time, and deleterious changes in risk factors for diabetes and cardiovascular disease, as well as the observational and clinical research on this topic in humans (7,8). We observed that breakfast skipping has also been linked to poorer overall dietary quality. Conversely, those who eat breakfast on a daily basis may benefit further in terms of obesity and disease prevention through, e.g., nutrient- and fiber-rich meals such as whole grain cereals (7–13).

Observational studies

Most cross-sectional studies that have examined the association between breakfast habits and measures of obesity (i.e. BMI) in adults report an inverse association, even with adjustment for potential confounding factors (14–17). Studies also tend to find that breakfast eaters report reduced intake of dietary fat and cholesterol (15,18,19) and increased fiber (15) relative to those who skip breakfast. Thus, the role of the quality of the breakfast meal, aside from its frequency, may have implications for daily energy, body weight changes, and chronic disease risk through a variety of mechanisms.

Only a few prospective studies have examined the associations between breakfast habits and body weight (20–22). In

[1] Published as a supplement to *The Journal of Nutrition*. Presented as part of the symposium entitled "Eating Patterns and Energy Balance: A Look at Eating Frequency, Snacking, and Breakfast Omission" given at the Experimental Biology 2009 meeting, April 19, 2009, in New Orleans, LA. This symposium was sponsored by the American Society for Nutrition Energy and Macronutrient Metabolism RIS, and was supported by an unrestricted educational grant from the Ingestive Behavior Research Center at Purdue University. The symposium was chaired by Megan A. McCrory and Wayne W. Campbell. Guest Editor for this symposium publication was Anna Maria Siega-Riz. Guest Editor disclosure: No conflicts to disclose.
[2] Supported by the Minnesota Obesity Center, the Minnesota Medical Foundation, and the General Clinical Research Center supported by the NIH.
[3] Author disclosures: M. Pereira, E. Erickson, P. McKee, K. Schrankler, S. Raatz, L. Lytle, and A. Pellegrini, no conflicts of interest.
[4] Supplemental Table 1 is available with the online posting of this paper at jn.nutrition.org.
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First published online December 1, 2010; doi:10.3945/jn.109.114405.

1 study, increased meal frequency (meals per week) was associated with a 45% reduced risk for obesity [odds ratio = 0.55 (95% CI = 0.33, 0.91)] in adults (22), whereas skipping breakfast appeared to be associated with a significant increase in risk of developing obesity (22). Among male health professionals, inverse associations were observed between breakfast cereal intake and BMI and between breakfast cereal intake and weight gain (21). In addition, those who consumed ≥1 serving/d (equal to a slice of bread, ~30 g) of either whole (P-trend $<$ 0.0001) or refined (P-trend $<$ 0.005) grain cereals had lower body weights than infrequent cereal consumers.

Recently, Timlin et al. (20) reported a prospective analysis of breakfast frequency and 5-y body weight change in the Project Eating Among Teens cohort of 2216 adolescents. Surveys were completed at baseline and 5 y later, with BMI, breakfast habits, and lifestyle and demographics measured over time. Frequency of breakfast (days per week in 3 categories: – 0, 1–6, 7 d) was inversely associated with weight gain and appeared to be a dose-response association ($P < 0.01$) (**Fig. 1**). Interestingly, adjustment for weight-related variables such as dieting and weight concerns partially attenuated this association. Future studies should further examine the role of breakfast habits among youth who are particularly concerned about their weight.

Potential mechanisms. Breakfast frequency (days per week) and quality may contribute to appetite regulation, quality of diet, and prevention of obesity and chronic disease through a variety of mechanisms (**Fig. 2**) (7). Many studies have reported that ready-to-eat breakfast cereal (14,23–25) and other fiber-rich foods (13,14,23,26,27) are associated with lower risk of obesity (11,14,28,29). Intake of fiber-rich breakfast foods may improve blood sugar control and possibly prevent low blood sugar between meals (28,30,31). In terms of appetite, some studies report enhanced feelings of satiation (32,33) and satiety (34,35) following ingestion of these types of foods but not after breakfasts low in fiber and/or high in fat (36). Perhaps these effects are explained by release or activity of gut hormones, including cholecystokinin (37–39) or other incretin hormones (40–46). Additionally, resistant starches are susceptible to colonic fermentation that may lead to the production of SCFA which, upon entering the circulation, may attenuate hepatic glucose output and serum FFA (47,48) and stimulate glucagon-like peptide-1 secretion (49,50). These effects could modulate insulin sensitivity and secretion patterns in important ways that relate to satiety and reduced risk of type 2 diabetes and possibly of cardiovascular disease and cancer. Preliminary breakfast feeding studies suggest that eating, rather than skipping, breakfast may reduce fasting total and LDL cholesterol (51,52), oxidized LDL (53), and serum triglycerides (54). Furthermore, slow absorption and digestion of starch at one meal (i.e. breakfast) may improve carbohydrate tolerance at the following meal (12,28,30,31,55,56).

In summary, the literature suggests that regular consumption of breakfast, and especially whole-foods, fiber-rich breakfasts, may be protective against obesity and chronic diseases. Results from a few, small, short-term randomized trials of breakfast behavior provide somewhat inconsistent results, with some positive and some negative findings, but overall they do provide some support for the hypothesis that regular consumption of a breakfast meal may reduce the risk of obesity and chronic disease (52,57–59). More definitive randomized controlled trials will provide answers to these important public health questions regarding pathways of dietary behaviors, dietary composition, and risk of obesity and related chronic diseases.

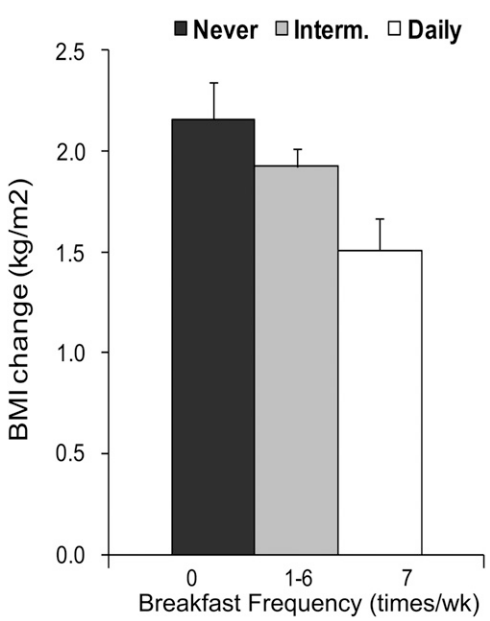

FIGURE 1 Association between change in BMI and change in breakfast frequency in 2216 adolescent boys and girls from the Project Eating Among Teens cohort study. Data are means ± SEM adjusted for baseline BMI, baseline breakfast frequency, age, and gender. Adapted with permission from (20).

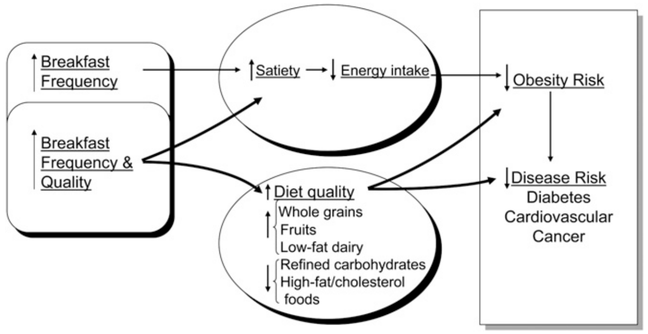

FIGURE 2 Theoretical model of breakfast frequency and quality in the development of obesity and chronic diseases. Reproduced with permission from (7).

Pilot experimental studies in adults and children

We recently conducted 2 pilot studies, in adults and children, to compare the effects of eating compared with skipping breakfast (breakfast frequency) and of breakfast type [particularly differences in fiber, glycemic index (GI),[8] and macronutrients] on perceived hunger, perceived energy levels, and glycemia and insulinemia. Study 1 examined the acute effects of breakfast frequency and composition (type of foods and beverages) on glycemia and perceived appetite and energy in adults. Study 2 compared the effects of breakfast frequency and composition on perceived appetite, energy levels, and mood in children. These studies were approved by the Human Subjects Committee of the University of Minnesota Internal Review Board, and all partic-

[8] Abbreviations used: AUC, area under the curve; GI, glycemic index; HCHG, high-carbohydrate, high-glycemic index treatment; HCLG, high-carbohydrate, low-glycemic index treatment; LCHG, low-carbohydrate, high-glycemic index treatment; LCLG, low-carbohydrate, low-glycemic index treatment.

ipants signed informed consent documents to participate in this research.

Study 1. In Study 1, in adult participants, we investigated the effects of breakfast meals varying in GI and carbohydrate amount on postprandial serum glucose and insulin concentrations as assessed by 120-min incremental area under the curve (AUC). Glycemic load was altered by manipulating the amount of carbohydrate and type (GI) in the meal. A randomized, within-person crossover study of 9 overweight young adults aged 20–40 y of age received 1 of 4 breakfast meals or water. Exclusion criteria included those who participated in regular physical activity, meeting or exceeding government recommendations, having a chronic or acute illness, taking medications, cigarette smoking, moderate to high alcohol intake, or allergies or aversions to any of the foods provided in the study. Participants were recruited through advertisements at the university and surrounding community. The breakfast meals were composed of either a high or low amount of carbohydrate and high- or low-GI foods. The composition of the test meals is shown in **Table 1** and **Supplemental Table 1** and were matched on energy content. Appetite ("How hungry do you feel at this moment?"), palatability ("How much did you like the meal?") and mood/ energy levels (e.g. "How energetic do you feel at this moment?") were answered by selecting a number from a Likert scale administered just before eating and at 30 min following the breakfast meal and up to 5 h. Scales included the terms "not at all" on the low end and "extremely" on the high end. Postprandial glucose and insulin concentrations were measured over 5 h, with blood samples taken i.v. every 30 min. Samples were assayed for glucose by an enzymatic heterogeneous sandwich immunoassay using the VITROS 950 chemistry system (Ortho-Clinical Diagnostics) according to the supplier's instructions. Insulin concentrations were measured by a commercial double-antibody RIA that shows little cross-reactivity (<0.2%) with proinsulin and a within-assay CV of 4% (Linco Research). The study took place at the General Clinical Research Center of the University of Minnesota.

Incremental areas under the response curves (AUC) for glucose insulin from 0 to 2 h after breakfast were calculated using the trapezoidal rule, ignoring the area beneath the premeal value (54,7). Specific time points of palatability, appetite, and mood were also investigated, and AUC was also calculated for appetite and mood. We used SAS software version 8.2 for all statistical analyses (SAS Institute) (55). The PROC MIXED program was used to perform repeated-measures regression to examine the effects of the breakfast meal on the 2-h glucose and insulin AUC. The independent variable was the breakfast treatment expressed as a 5-level class variable. The 5 levels were: *1*) high carbohydrate and high GI (HCHG); *2*) high carbohydrate and low GI (HCLG); *3*) low carbohydrate and high GI (LCHG); *4*) low carbohydrate and low GI (LCLG); and *5*) water only. Estimate statements were written to test the main hypotheses of the study, comparing the AUC between high- and low-GI meals, holding constant the carbohydrate amount, and the AUC between high- and low-carbohydrate amount, holding GI constant. Gender and BMI were examined in the models as covariates that may influence the effects. Results are presented as the mean differences between treatments and their SE and 2-sided *P*-values for the hypothesis tests. As an additional secondary analysis, we examined the potential impact of the different meals on reactive hypoglycemia at the 5-h postprandial point. The 5-h glycemia was computed as the difference between glucose concentration at 5 h and the initial prebreakfast baseline glucose value. A *P*-value of < 0.05 was considered significant.

We found that the mean serum glucose 120-min AUC was significantly higher following the high- GI breakfast meals compared with the low-GI breakfast meals independent of carbohydrate amount ($P = 0.005$) (**Fig. 3**). Glucose AUC did not differ between the high-carbohydrate and low-carbohydrate breakfast meals that had similar GI values. Insulin AUC did not differ between the high-GI and low-GI breakfast meals that had similar amounts of carbohydrate. However, the postprandial 5-h drop in blood glucose was similar following the HCHG meal to that following the skipping breakfast/water-only condition, presumably an effect of the hyperinsulinemia produced by the high-glycemic load condition. In conclusion from this study, lowering the GI of a breakfast meal, but not necessarily total carbohydrate amount, reduced postprandial glucose concentrations in healthy, overweight young adults. Interestingly, a high-glycemic load diet, rich in high-GI foods, may lead to reactive hypoglycemia such that the drop in blood sugar 5 h after the meal may resemble that experience after skipping the breakfast meal altogether. Thus, consuming low-GI breakfast foods as part of whole meals may reduce hyperglycemia in healthy individuals and prevent reactive hypoglycemic between meals, important effects for the prevention or management of diabetes mellitus.

Study 2. In Study 2, we hypothesized that children will be less hungry, more energetic, and in a better mood when a breakfast

TABLE 1 Macronutrient composition of 5 breakfast meals in Study 1: adults[1]

Meal	Protein	Fat	Carbohydrate	Dietary fiber	Diet GI	Diet GL
		% energy		*g*		
HCHG	15.1	19.5	65.5	3.96	66.3	58.6
HCLG	15.8	20.0	64.2	17.33	42.2	36.0
LCHG	15.0	40.7	44.4	2.50	64.0	38.3
LCLG	15.3	40.6	44.1	14.23	41.0	24.3
Water	0	0	0	0	0	0

[1] GI, glycemic index (using white bread as 100%); GL, glycemic load (GI x grams of carbohydrate).

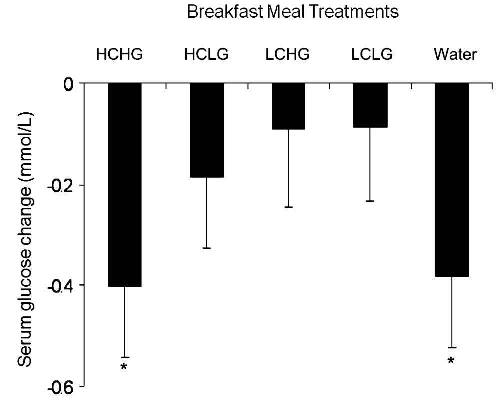

FIGURE 3 Changes in the serum glucose concentrations of adults between 0 and 300 min after ingestion of 5 test breakfast meals differing in amount and type of carbohydrate (Study 1). Values represent the mean − SEM, $n = 9$. *Concentrations changed over time, $P \leq 0.01$. The conditions did not differ from one another, $P > 0.05$.

was consumed compared with when a breakfast was skipped. Further, this study assessed the effects of a balanced breakfast of whole grains, fruit, and milk (whole) compared with a breakfast high in refined carbohydrates of pastry items and fruit juice (refined). We therefore further hypothesized that eating a whole grain breakfast may also result in children being less hungry, more energetic, and in a better mood compared with eating a refined breakfast. We used a crossover experimental design to compare the effects of 3 separate breakfast conditions on appetite and mood in children ages 9–13 y. Each child received the 3 breakfast conditions, 1 time for each condition, over a span of 2 wk, with at least 1 washout day between each condition. Following the breakfast meal, participants were tested throughout the morning to assess appetite, mood, and perceived energy levels. Twenty-eight participants completed the study during the summer of 2006. Participants were recruited to the study, approved by the University of Minnesota Human Subjects Committee, from the Minneapolis Park and Rec Plus+ summer daycare programs at 4 participating community centers, where the study took place with approval from the Minneapolis park system and signed consents from the children and their parents. Twenty-eight children (14 boys and 14 girls) ages 9–13 y (mean age 10.4 y) starting the 5th to 7th grades who were in good health without chronic disease or food allergies were enrolled in the study. The mean BMI was 20.2 kg/m^2 and the sample was ethnically diverse with 17 Caucasians, 5 African Americans, 3 Native Americans, 1 Hispanic, 1 Asian, and 1 "other."

The 3 breakfast conditions, given in random order to each child on separate days, were: *1*) a balanced meal of whole grains (bread or cereal found to be acceptable to children in preliminary testing), milk, and fruit (whole condition); *2*) a refined carbohydrate breakfast of a pastry and fruit drink (refined condition); and *3*) water, artificially sweetened flavored water, or diet drink (skipped condition). All breakfast meals were matched in energy content at ~550 kJ/meal. Children were encouraged but not pressured to eat the entire meal and a visual estimate of plate waste was recorded by the cook when the children were finished eating. Standardized scales were adapted from the literature and are currently being used in other dietary interventions to assess appetite and mood on Likert scales (20,21). Children in the skipped group were given a granola bar and fruit drink to prevent any adverse affects from not eating for the entire length of the testing period per the requirement of parents and the Human Subjects Committee. At 3.5 h after eating breakfast, the Appetite and Mood Questionnaire and Cognitive assessments were repeated.

As in Study 1, we used SAS software version 8.2 for all statistical analyses (SAS Institute) (55). The PROC MIXED program was used to perform repeated-measures regression to examine the effects of the breakfast meal on the dependent variables of appetite, perceived energy, and mood ratings. The independent variable was the breakfast treatment, expressed as a 3-level class variable representing the 3 conditions described above. Estimate statements were written to test the main hypotheses of the study similar to those for Study 1 above. Gender and BMI were examined in the models as covariates that may influence the effects, but these had no meaningful impact on the results (data not shown). Results are presented as the mean differences between treatments and their SE and 2-sided *P*-values for the hypothesis tests. $P < 0.05$ was considered significant.

The results indicate that the children equally enjoyed the whole food and refined foods breakfasts and that both breakfasts had a similar effect on satiation compared with skipping breakfast. Of the 28 participants, 4 had no plate waste for either breakfast condition. Eleven children ate everything during the refined condition but left some food or beverage unconsumed during the whole condition. The most common source of plate waste was leaving milk in the cereal bowl. At 2 h, the differences in hunger levels between skipping and eating breakfast were very strong ($P < 0.0001$). The difference was gone at 3.5 h because of the snack that was required for those who skipped breakfast. Hunger levels appeared to increase over time for the whole and refined conditions but did not significantly differ from each other. At 2 h after breakfast, the variable "How tired do you feel right now?" had a significantly higher score for skipped compared with eating the whole food breakfast ($P = 0.02$) and skipped compared with eating any breakfast ($P = 0.03$). Although not significant, there were some trends toward feeling more tired and lazy for skipped compared with eating the refined foods breakfast 2 h following breakfast. At 3.5 h after breakfast, no significant differences or trends were noted.

Again, recall that the children were given a mid-morning snack during the skipped breakfast condition. At 2 h after breakfast, the values for feeling tired were (mean ± SE): whole foods = 1.6 ± 0.27, refined foods = 1.9 ± 0.28, skipped breakfast = 2.4 ± 0.27. The last differed from the value for eating any breakfast ($P = 0.03$). At 2 h following breakfast, the mean values for feeling lazy were: whole foods = 1.5 ± 0.32, refined foods = 2.0 ± 0.33, skipped breakfast = 1.9 ± 0.33. The values for whole foods and refined foods tended to differ ($P = 0.09$).

One limitation of this study was that children received each breakfast treatment only 1 time. It would be desirable to give children each breakfast condition for an extended period of time to capture a better assessment of the effects of the separate conditions. In addition, a larger study with more participants, possibly involving students in a multi-school arrangement, would bring more power to the results found. Another limitation was that a standard amount of each breakfast type was given to all children, independent of a child's individual factors such as size, weight, or usual breakfast habits and intake levels. Although no children in the current study requested more food at breakfast, there should be a provision for those who normally eat more at breakfast and want more than what was provided to truly assess children in this category. Finally, it was felt that a mid-morning snack was necessary for the no breakfast group to avoid any ill effects from not eating for an entire morning. This changed the eating condition, but was an ethically necessary decision. Strengths of this study include that children were assessed in a real-life situation rather than a clinical setting, where behaviors and reactions may be affected by unfamiliar surroundings. In addition, children were given ordinary foods that are routinely found in the grocery store, rather than unfamiliar items such as glucose drinks or fiber enhancers, to clinically establish nutrient intake. Another strength of this study is that it targeted an important age group, one that is at risk for increased breakfast skipping and its associated implications as they get older.

Conclusions

Breakfast consumption is associated with lower BMI in adults in a number of cross-sectional studies. The few prospective studies on this topic are generally supportive of the cross-sectional findings. Pilot experimental studies in adults and children suggest that both breakfast frequency (skipping compared with eating) and the composition of the meal may have important effects on a variety of factors related to appetite control and control of blood sugar and insulin. The results suggest that breakfast frequency (especially daily consumption) and quality (foods such as fiber- and nutrient-rich whole grains, fruit, and low-fat dairy) may be related in causal ways to appetite controls and blood sugar control, supporting the hypothesis that the breakfast meal and its quality may have important causal implications for the risk of obesity and type 2 diabetes. Future studies on this topic should further address these potential mechanisms, particularly in larger and longer trials. Because a large percentage of the U.S. population skips breakfast, effects of regular breakfast on public health may be significant. It may therefore be important to place more emphasis on breakfast habits, especially among youth, when behavioral patterns are developing.

Acknowledgments

M.A.P. designed the research, analyzed data, wrote the paper, had primary responsibility for final content. E.E. contributed to data collection, data analysis, and paper writing, and approved the final manuscript. P.M. collected data, contributed to writing the paper, and approved the final manuscript. K.S. collected data, contributed to writing the paper, and approved the final manuscript. S.K.R. assisted in study design, data collection, writing the paper, and approved the final manuscript. L.A.L. assisted in study design, data collection, analysis and interpretation, writing the paper, and approved the final manuscript. A. D.P. assisted in study design, data collection, analysis, and interpretation, writing the paper, and approved the final manuscript. All authors read and approved the final manuscript.

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