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Breakfast Frequency and Quality in the Etiology of Adult Obesity and Chronic Diseases

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The frequency of eating breakfast has declined over the past several decades, during which time the obesity epidemic has also unfolded. Therefore, there is growing scientific interest in the possible causal role of breakfast in weight control and related disease risks. We conducted a MedLine search for studies that addressed meal frequency, breakfast consumption, and chronic disease risk. Clinical studies document that regular meal consumption can potentially reduce the risk of obesity and chronic disease through mechanisms involved in energy balance and metabolism. Many observational studies have found that breakfast frequency is inversely associated with obesity and chronic disease, but this literature does have some important limitations. Only four relatively small and short-term randomized trials have examined breakfast consumption and body weight or chronic disease risk, with mixed results. Large, long-term, randomized trials are needed.

Key words: body weight, breakfast, cereal, chronic disease, meal frequency, obesity

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BACKGROUND AND SIGNIFICANCE

Obesity, due to its high prevalence and associated chronic illnesses, is one of the more pressing public health problems today.[1,2] The escalating rate of obesity over the past several decades is likely due to widespread environmental changes that encourage sedentary lifestyles and increased energy intake and their interaction with genetic factors. Scientists and medical and public health practitioners 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 intriguing line of research that may have broad public health application in this regard is the breakfast meal and the frequency in which it is eaten in driving such important factors as appetite control, dietary quality, and chronic disease risk. For a number of behavioral and physiological reasons described in detail below, the breakfast meal may be of unique importance. Therefore, our aim was to review the published scientific literature on the association between breakfast habits and body weight regulation and related chronic disease risk in adults.

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METHODS

Literature was initially gathered through the investigators' personal research files, then by scanning the references of the articles on hand, and finally by conducting a MedLine search through September 2006. Due to the lack of any standard definition of breakfast in the literature, we came up with a rather broad definition of breakfast for inclusion criteria. We defined breakfast 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 am, and of a calorie level between 20% and 35% of total daily energy needs. Articles that met this definition of breakfast and either discussed it in relation to meal frequency, appetite, satiety, energy intake, energy expenditure, or the thermic effect of food (TEF) or that included end points of body weight, body weight change, body mass index (BMI), obesity, weight loss, and chronic disease risk factors were reviewed for possible inclusion.

POTENTIAL MECHANISMS FOR BENEFICIAL EFFECTS OF BREAKFAST CONSUMPTION

There are a number of physiological mechanisms whereby meal skipping, and breakfast skipping in particular, may lead to up-regulation of appetite, possibly leading to weight gain over time and deleterious changes

in risk factors for diabetes and cardiovascular disease (CVD). Breakfast skipping has also been linked to poorer overall dietary quality. Since the breakfast meal commonly includes cereal,[3] individuals who eat breakfast on a regular basis may benefit from a number of physiological mechanisms hypothesized to reduce appetite and subsequently chronic disease risk (Figure 1).

Appetite Control

Clinical studies in humans have consistently found that increased meal frequency induces changes in metabolism that may improve risk factors for chronic disease[4-12] and reduce appetite and energy intake.[13-16] Studies addressing regular breakfast consumption have found that the consumption of a dietary pattern that includes ready-to-eat cereal[17-20] and other relatively high-carbohydrate and fiber-rich foods (i.e., whole grains, fruit)[17,18,21-23] is associated with a lower BMI, perhaps through beneficial effects on satiety.[18,24-26] Clinical studies have documented that the consumption of fiber-rich breakfast foods blunts postprandial glycemic and insulinemic responses, improves insulin sensitivity, and reduces between-meal hypoglycemia.[24,27,28] These metabolic changes may prevent weight gain through effects on satiety and subsequent energy intake.[29] Additional clinical studies examining subjective end points of hunger and satiety following breakfast consumption document increased feelings of fullness[30,31] and satiety[32,33] following the consumption of these types of foods, but not following the consumption of breakfasts high in different types of fat.[34]

Complex-carbohydrate-containing foods, such as the whole grains commonly consumed at breakfast, may affect the release or activity of gut hormones, including cholecystokinin (CCK), that may act as satiety factors.[35] Clinical studies have documented prolonged increases in circulating levels of CCK following the consumption of fiber-rich meals relative to energy-matched, low-fiber meals.[36,37] Other incretin hormones, including gastric inhibitory peptide (GIP) and glucagon-like peptide-1 (GLP-1), may also mediate postprandial insulin secretion,[9,38,39] regulate postprandial satiety,[39-41] and play a role in insulin-independent glucose disposal.[42,43] Lastly, whole grains and other plant foods may exert satiety-related effects through the fermentation of fiber and resistant starch in the colon. Certain types of starch are resistant to digestion in the small intestine, making them susceptible to fermentation in the colon. Short-chain fatty acids, products of this fermentation process, may enter the portal circulation, reduce hepatic glucose output and serum concentrations of free fatty acids,[44,45] and stimulate glucagon-like peptide-1 secretion.[46,47] These metabolic changes may then alter insulin sensitivity, insulin secretion patterns, and regulation of satiety.

One last relevant area is that the time of day in which food is consumed may influence appetite and overall energy intake. De Castro et al.[48] investigated the relationship between time of day of food intake and total daily energy intake in 867 individuals (375 men and 492

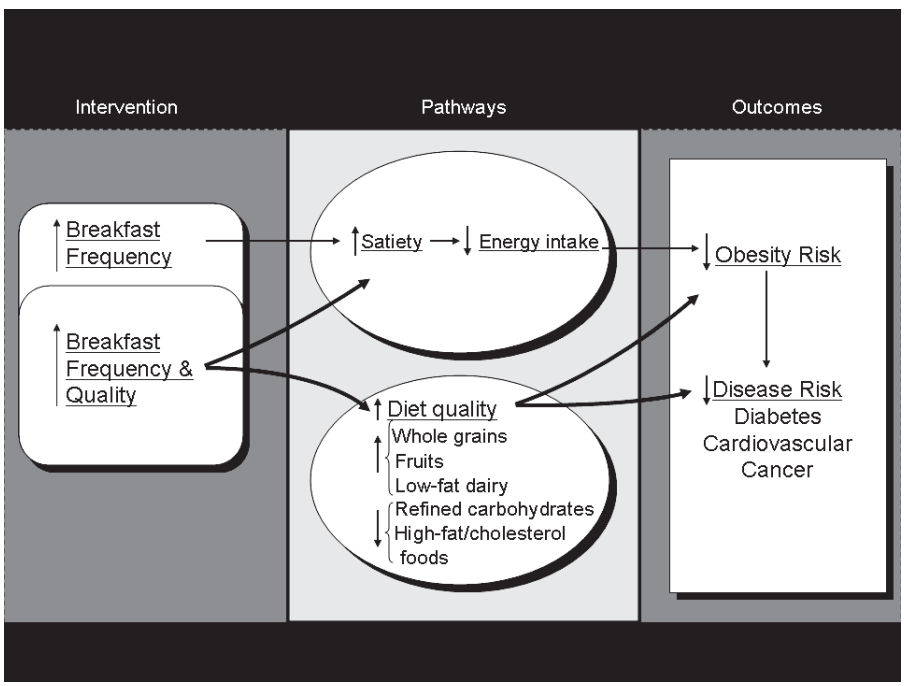

Figure 1. Theoretical model of breakfast frequency and quality in the development of obesity and chronic diseases.

women), and found that the proportion of intake in the morning was negatively correlated with overall intake ($r = -0.13$, $P < 0.01$), while the proportion of intake consumed late in the day was positively correlated with overall intake ($r = 0.14$, $P < 0.01$), potentially increasing the risk for weight gain and obesity. Further examination of the data identified that meal sizes (in MJ) increased over the day, while the time between meals (after-meal interval) decreased over the same period, suggesting that food intake in the morning (i.e., breakfast) is particularly satiating and has the potential to reduce the total amount of energy consumed during the day.

In summary, physiologic changes observed with increased meal frequency and regular breakfast consumption can lead to increased satiety and reduced energy intake. Therefore, individuals who consume breakfast regularly may be at reduced risk for chronic diseases, particularly if the breakfast meal includes whole-grain products.

The Thermic Effect of Food

The amount of energy expended following meal consumption, the thermic effect of food (TEF), is another mechanism that may contribute to energy imbalance.[49-51] Clinical studies have examined the role of meal frequency on TEF in both the chronic and acute feeding states.[12,52-57,58] In general, there are mixed results, with some studies documenting an increase in TEF following both infrequent[55] and frequent[56] meals and one study showing no significant effect over 10 hours.[58] Therefore, studies done to date examining the impact of meal frequency on postprandial TEF have reached inconclusive results and warrant further research.

The composition of meals in relation to TEF has also been explored. One chronic feeding study in which subjects consumed a high-fat, high-carbohydrate, or mixed meal of fixed energy intake found that the high-carbohydrate diet led to a negative fat balance, suggesting that this type of diet may be effective in fuel partitioning and may have longer-term effects on body fat stores.[59] Acute feeding studies in which the proportion of macronutrients was manipulated at breakfast have observed mixed results.[60-62,63,64] Stubbs et al.[61] observed no significant difference in energy expenditure when comparing breakfasts with similar energy densities high in protein, carbohydrate, or fat. Another study that added a breakfast high in alcohol found 5-hour TEF to be significantly higher in the alcohol-containing breakfast, followed by the high-protein breakfast.[60] Interestingly, no difference in postprandial hunger, satiety, or energy intake was observed up to 5 hours after meal consumption. The effect of high-carbohydrate/low-fat or low-carbohydrate/high-fat breakfasts with fixed energy intakes of 600 or 1200 calories has also been examined.[62] Although there was no significant effect of meal composition on TEF, meals with a higher energy content were associated with 5-hour TEF values significantly greater than those with low energy content.

Similar results have been documented in lean and obese men, in whom no significant change in postprandial energy expenditure was observed following consumption of a high-fat (approximately 45%–50% of total intake) breakfast meal,[63,64] regardless of the fat level of their habitual diet.[63] Lastly, studies on the effect of high-protein breakfasts (approximately 30% of total intake) on postprandial energy expenditure have documented that TEF was significantly higher following consumption of high-protein meals.[65, 66] The TEF accounted for most of the increase in postprandial energy expenditure (approximately 90 additional calories burned per day), suggesting that breakfasts high in protein may contribute to the efficacy of weight loss.[66] Overall, these findings document that the composition of a meal can contribute to postprandial TEF in various degrees, with meals high in protein exerting the largest effect.

In summary, results from studies manipulating either meal frequency or composition and their subsequent effect on postprandial energy expenditure remain inconclusive. This may be due in part to methodological variations in the measurement of TEF.[67] Additional studies in this area are warranted but require a standardized measurement protocol to help control for or eliminate discrepant results.

Glucose and Lipid Metabolism

The reduction of chronic disease risk is postulated to arise from day-long changes in glycemia and insulinemia observed with frequent meal intake (i.e., a regular meal pattern). Early clinical studies documented increased serum insulin and free fatty acid concentrations, as well as increased rates of de novo lipogenesis (newly synthesized fatty acids), with a meal frequency pattern representative of gorging (infrequent large meals).[7,68] From these early studies, it has been suggested that the frequency with which foods are consumed may be inversely related to obesity. Further human clinical studies documented that lower day-long insulin concentration leads to reduced concentrations of total cholesterol[5,8,69-71] and low-density lipoprotein (LDL) cholesterol,[8,72] apolipoprotein B,[8] and prolonged suppression of serum free fatty acids, gastric inhibitory peptide, and growth hormone when meals were consumed more frequently.[73] In cross-sectional studies, similar results have been observed in that lower total cholesterol[74,75] and LDL cholesterol[74] were observed when meals were consumed

frequently versus sparingly. Together, the metabolic changes observed in these studies suggest that frequent meal intake (i.e., a regular meal pattern) may reduce the risk of lipid-associated chronic diseases such as obesity, CVD, and diabetes mellitus.

In addition to the impact of meal frequency on lipid metabolism, the effects of the consumption of the breakfast meal have also been examined.[12,13,28,76,77] Results from breakfast feeding studies lend support to meal frequency studies in that reductions in fasting total and LDL cholesterol,[12,13] oxidized LDL,[77] and serum triglyceride concentration[76] were observed when breakfast was consumed compared with when it was omitted. From the results of these studies, it has been postulated that reduced day-long serum insulin concentration may decrease hepatic cholesterol production through the inhibition of 3-hydroxy-3-methyl-glutaryl-CoA reductase.

A second mechanism more directly related to glucose metabolism suggests that economy of insulin secretion at one meal may improve insulin sensitivity and glucose tolerance at a subsequent meal. Clinical studies documenting the absorption characteristics of foods indicate for the most part that slow absorption and digestion of starch at one meal (i.e., breakfast) may improve carbohydrate tolerance at the following meal.[14,24,27,28, 78,79] This characteristic has been observed in both the fasted[78] and fed states.[14,24,27,78,79] Additional clinical studies documented similar findings when an oral glucose challenge was conducted after the consumption of a high-carbohydrate, low-fat breakfast compared with a moderate-fat breakfast.[80,81] Lastly, whole grain intake, frequently consumed at the breakfast meal, has been found to be significantly associated with improved insulin sensitivity in epidemiological studies.[22,82] Together, findings from both clinical and observational studies suggest that dietary patterns that include frequent smaller meals—in particular, habitual diets that include regular breakfast intake including whole grains—are associated, likely in a cause-and-effect manner, with improved glycemia, insulinemia, and lipidemia.

Dietary Composition

Another important general pathway through which regular breakfast consumption may reduce the risk of chronic diseases is its potential impact on the composition of the overall diet. Numerous observational studies have observed that regular breakfast eaters have higher dietary quality (e.g., higher fiber and nutrient intakes and lower energy density) relative to breakfast skippers.[19,20,83-89] These associations appear to be consistent and independent across a number of studies in various populations, and the findings can be inferred to be directly related to chronic disease risk.[90] Prospective and cross-sectional studies including the National Heart, Lung, and Blood Institute Growth and Health Study,[19,20] the Continuing Survey of Food Intake by Individuals (CSFII),[3,88] the Nationwide Food Consumption Surveys (NFCS),[86,91] and the National Health and Nutrition Examination Surveys (NHANES) II[92] and III[18] have all documented a number of positive associations between breakfast consumption and diet adequacy. In general, those who consume breakfast regularly exhibit a nutrient profile high in fiber, calcium, vitamins A and C, riboflavin, zinc, and iron, and low in dietary fat, cholesterol, and caloric intake. In a number of these studies, the consumption of breakfast cereal in particular was noted to contribute to an improved nutrient profile.[19,86,87,89,92] In contrast, those who skipped breakfast were unable to meet nutritional recommendations from meals consumed throughout the remainder of the day. Overall, these studies document that regular breakfast consumption is associated with improved diet quality and better food choices throughout the day. A few small clinical studies are supportive of these observations.[85,93]

Summary of Mechanisms Linking Breakfast Habits to Obesity and Disease Risk

In summary, there are myriad mechanisms through which breakfast habits may reduce the risk of obesity and chronic diseases. The frequency of meal consumption appears to bring about metabolic changes involved in the regulation of glycemia, insulinemia, lipid metabolism, and possibly appetite and energy balance. In the fed state, insulin plays a central role in satiety, fatty acid and cholesterol synthesis, and glucose tolerance. When the postprandial insulin response is blunted but maintained at a constant low level, a reduction in appetite between meals has been observed, which has the potential to decrease total daily energy intake and risk for obesity. Reductions in serum total and LDL cholesterol, apolipoprotein B, and triglycerides are also observed with a reduced postprandial insulin response, exerting an effect that may substantially reduce the risk for the development of CVD. The economy of insulin secretion at one meal also has the potential to affect insulin sensitivity and glucose tolerance at subsequent meals, further reducing the risk for the development of chronic disease. Although inconsistent, additional studies suggest that the frequency and composition of meals affect postprandial energy expenditure, suggesting a role of these factors in chronic disease risk as well.

Many surveillance and cohort studies of population samples have indicated a robust direct and seemingly independent association between the frequency of breakfast eating and overall dietary adequacy/quality. Together, these metabolic and behavioral changes brought about through the consumption of breakfast, and espe-

cially of slowly absorbed, fiber- and nutrient-rich foods commonly consumed at breakfast, allude to the importance of meal frequency and meal composition in risk reduction for chronic diseases including obesity, heart disease, and type 2 diabetes. Whether the manipulation of breakfast habits has a truly important causal effect on obesity and chronic disease awaits investment in sufficiently large, long, and well-designed controlled trials.

OBSERVATIONAL STUDIES OF BREAKFAST HABITS, OBESITY, AND CHRONIC DISEASE RISK

There have been numerous observational studies examining the associations between meal frequency and risk of obesity and chronic disease. Their equivocal findings are possibly due to limitations and inconsistencies in the methodologies and study designs. The following sections describe the epidemiologic literature on the specific topic of breakfast habits in relation to the end points of interest, obesity and chronic disease risk.

Body Weight and Obesity Risk

Four cross-sectional studies have examined the association between breakfast habits and measures of obesity (i.e., BMI) in adults (Table 1).[18,94-96] A recent publication of data from the NHANES III (1999–2000) reports an inverse association between breakfast consumption and BMI.[94] Regular breakfast consumption was significantly associated with having a BMI < 25 kg/m^2 in women but not in men. Women who reported eating breakfast were significantly less likely to be overweight (BMI > 25 kg/m^2) than women who reported skipping breakfast (OR = 0.76, 95% CI 0.57, 1.01, $P = 0.05$). Interestingly, intake of ready-to-eat breakfast cereal appeared to explain the difference between genders for the association between breakfast habits and body

Table 1. Cross-Sectional Studies of Breakfast Habits, Body Weight, and Obesity Risk In Adults

Author/Year	Sample	Study Title	Variable Measured	Results
Song et al., 2005[94]	Underweight, normal-weight, overweight, and obese adults (2097 M, 2121 F)	NHANES III (1999–2000)	Breakfast and RTEC consumption (via 24-h dietary recalls) and BMI	Inverse association between breakfast consumption and BMI (OR 0.76, 95% CI 0.57, 1.01, $P = 0.057$) and RTEC consumption and BMI (OR 0.70, 95% CI 0.52, 0.94, $P < 0.05$) in women
Wyatt et al., 2002[96]	Normal-weight adults (607 M, 2350 F)	National Weight Control Registry	Breakfast consumption (via food habits questionnaire and self-reported number of days breakfast typically eaten per week)	78% consumed breakfast daily,which is 3-fold higher than general population ($P < 0.001$)
Cho et al., 2003[18]	Underweight, normal-weight, overweight, and obese adults (7867 M, 8765 F)	NHANES III (1988–1994)	Breakfast type (via 24-h dietary recall) and BMI	Lower BMI with RTEC, cooked cereal, and quick bread consumption ($P < 0.01$)
Summerbell, et al., 1996[95]	Normal-weight adults (220 M/F)	N/A	Feeding pattern (via 7-d diet records) and BMI	A high BMI was associated with lower energy intakes at breakfast in the adolescent ($P < 0.01$) and middle-aged group ($P < 0.05$)

BMI, body mass index; CI, confidence interval; NHANES, National Health and Nutrition Surveys; OR, odds ratio; RTEC, ready-to-eat cereal.

weight. In support of these findings, regular breakfast consumption was one of the most common behavioral factors found among individuals who reported losing an average of 26 pounds and keeping it off for an average of 6 years in the National Weight Control Registry.[96] Seventy-eight percent of the 2959 adults in the registry reported daily breakfast intake, a prevalence approximately 3-fold higher than daily breakfast reported by the general population.[96] One further study documented an inverse relationship between breakfast consumption and BMI.[95] In the adolescent age group, greater energy intakes at breakfast were associated with a lower BMI ($P < 0.01$). In the middle-aged group, a lower BMI ($P < 0.05$) was documented in individuals who consumed greater energy intakes at breakfast and lower intakes in the evening. Therefore, breakfast frequency and relative body weight have been found to be inversely associated in many cross-sectional studies in adults.

The composition of the breakfast meal has also been examined in relation to body weight in cross-sectional studies of adults (Table 1).[18,94] In one of two studies examining data from NHANES III (1988–1991, 1991–1994), breakfast type was described in 10 categories and examined in relation to BMI and energy intake.[18] A lower BMI was observed in individuals who consumed ready-to-eat breakfast cereal, cooked cereals, and quick breads ($P < 0.01$). In contrast, a higher BMI was found in breakfast skippers and those who consumed food from the meat and eggs category. Other studies documenting breakfast intake have observed reduced intake of dietary fat and cholesterol[86,92,94] and increased fiber[94] in individuals who consume ready-to-eat breakfast cereal, associations that may have implications for daily energy, body weight changes, and chronic disease risk through a variety of mechanisms.

To date, two prospective studies examining an association between breakfast habits and body weight have been conducted in adults (Table 2).[97,98] Data from the Seasonal Variation of Blood Cholesterol Study found increased meal frequency to be associated with a 45% reduced risk for obesity (OR = 0.55, 95% CI 0.33, 0.91) in adults.[98] On the other hand, skipping breakfast on a regular basis or at least once during the study was associated with a 4.5- and 1.3-fold increase in risk in developing obesity (OR = 0.45, 95% CI 1.57, 12.90; OR = 1.34, 95% CI 0.81, 2.20, respectively).[98] This observed increase in risk for obesity was likely due to the greater daily energy intake observed when breakfast was omitted, an observation previously documented by Schlundt et al.[93]

In the larger Physicians' Health Study, an inverse association between breakfast cereal consumption and BMI and weight gain has recently been documented.[97] At baseline and 8 years, individuals who consumed more than one serving per day of either whole-grain (P for trend < 0.0001) or refined-grain (P for trend < 0.005) breakfast cereal weighed significantly less than those in the lowest category (rarely ate) of intake. At the 13-year

Table 2. Prospective Studies of Breakfast Habits, Body Weight, and Obesity Risk in Adults

Author/Year	Sample	Study Title	Variable Measured	Results
Ma et al., 2003[98]	Normal-weight, overweight, and obese adults (251 M, 248 F)	Seasonal Variation of Blood Cholesterol Study (1994–1998)	Meal frequency (via three 24-h dietary recalls at three visits over one year), skipping breakfast, and BMI	Risk of obesity increased 4.5 times in breakfast skippers compared with breakfast consumers (OR 4.50, 95% CI 1.57, 12.90)
Bazzano et al., 2005[97]	Normal-weight adults (17,881 M)	Physicians' Health Study	Breakfast cereal (whole, refined, and total grain) intake measured (via a semiquantitative food frequency questionnaire) and BMI	Reduced risk of BMI $\geq$ 25 kg/m^2 at 8 (RR 0.78, 95% CI 0.67 to 0.91) and 13 (RR 0.88, 95% CI 0.76 to 1.00) years follow-up with consumption of $\geq$ 1 serving per day of all cereals; after adjustment, trend for BMI < 25 kg/m^2 not statistically significant when divided by type of grain (whole grain vs. refined grain)

BMI, body mass index; CI, confidence interval; OR, odds ratio; RR, relative risk.

follow-up, similar significant results were found only for those individuals consuming at least one serving per day of whole-grain cereal (P for trend < 0.05). Relative risks suggest that consumption of over one serving per day of any breakfast cereal reduces the risk of being overweight by 22% and 12% for the follow-up periods at 8 (RR = 0.78, 95% CI 0.67, 0.91) and 13 (RR = 0.88, 95% CI 0.76, 1.00) years.

Lastly, four observational studies have documented an association between diet patterns and BMI in adults (Table 3).[17,99-101] In a cross-sectional study of women in five facilities in Oahu, Hawaii, four specific diet patterns were observed: meat, vegetable, bean, and cold foods (i.e., cold cereals, fruits, and fruit juice).[17] After adjusting for daily energy intake, the meat pattern was found to be positively associated with BMI ($r = 0.17$), whereas the other three patterns showed inverse associations with BMI. In prospective studies, a diet pattern composed of whole grains, breakfast cereals, cooked oatmeal, reduced-fat dairy, fresh fruit, and fiber was found to be

Table 3. Observational Studies of Dietary Patterns, Body Weight, and Obesity Risk in Adults

Author/Year	Sample	Study Title	Variable Measured	Results
Maskarinec et al., 2000[17]	Normal-weight, overweight, and obese adults (514 W)	N/A	Breakfast pattern (via food frequency questionnaire) and BMI	Meat pattern positive association with BMI ($P = 0.0001$); bean and cold foods pattern, including RTEC, negative association with BMI ($P = 0.003$)
Schulz et al., 2005[99]	Normal-weight, overweight, and obese adults (24,958 M/F)	EPIC-Potsdam Study	Food pattern (via food frequency questionnaire) and weight change	Diet characterized by high intakes of whole-grain bread, grain flakes/cereals, fruits and fruit juices, predictive of subsequent weight change in non-obese subjects (P for trend < 0.0001)
Newby et al., 2004[100]	Normal-weight adults (459 M/F)	Baltimore Longitudinal Study of Aging	Food pattern (via 7-d food records), change in BMI, and waist circumference	Diet characterized by reduced-fat products, cereal, fruit, and fiber inversely associated with annual change in BMI ($\beta = -0.51$, 95% CI –0.82 to –0.20, $P < 0.05$) in women and annual change in waist circumference ($\beta = -1.06$, 95% CI –1.88 to –0.24, $P < 0.05$) in men and women
Koh-Banerjee et al., 2004[101]	Normal-weight adults (27,082 M)	Health Professionals Follow-up Study	Food pattern (via food frequency questionnaire) and 8-y weight gain	High whole grain intake inversely associated with weight gain (P for trend < 0.0001); for every 20 g/d increment in cereal fiber, weight gain reduced by 0.81kg (P for trend < 0.001)

BMI, body mass index; CI, confidence interval; RTEC, ready-to-eat cereal.

inversely associated with BMI[100] and weight gain[99,101] in normal and overweight subjects. In one study, cereal fiber in particular was found to be protective against 8-year weight gain, independent of fruit and vegetable fiber.[101] For every 20 g/d increase in cereal fiber intake, risk of weight gain was reduced by 0.81 kg (P for trend < 0.001). A similar dose-response relationship was observed for whole grain (P for trend < 0.0001) and bran intake (P for trend $= 0.01$). This food pattern was less predictable of weight change, however, in obese subjects in the EPIC-Potsdam cohort,[99] and was not significantly associated with change in BMI in men in the Baltimore Longitudinal Study of Aging.[100]

In summary, observational epidemiological studies provide good support for an inverse relationship between breakfast frequency and relative body weight and obesity risk in adults. The consumption of ready-to-eat breakfast cereal and associated foods and food components (i.e., fruits, whole grains, fiber) has also been found to be associated with a lower BMI. Together, these studies suggest that both the consumption and composition of breakfast may play a role in weight control and risk for chronic disease.

Chronic Disease Risk

Many dietary factors, including total and saturated fat consumption, fruit and vegetable intake, and cereal and dietary fiber, have been shown to affect risk for chronic disease.[102-105] When considering the role of breakfast consumption on chronic disease morbidity and mortality, studies have documented a positive association between regular breakfast intake (i.e., cereals and whole-grain foods) and reductions in morbidity and mortality from a variety of causes (Table 4).[106-109] In the Alameda County Study, eating breakfast on a regular basis was one lifestyle factor found to be protective against total and CVD-related death.[108] Furthermore, an increased risk of death was observed in breakfast skippers relative to breakfast eaters (RR = 1.46, 95% CI 1.17, 1.83).[108] Additional studies have examined daily intake of whole grains with risk of chronic disease mortality and have documented similar results.[106,107,109] One of these studies that was specific to whole grain intake at the breakfast meal documented a graded inverse association between whole grain breakfast intake and total (RR = 0.73), CVD-related (RR = 0.72), and myocardial infarction mortality-related (RR = 0.77) death in 86,190 men.[109] These associations remained when the data were adjusted for CVD risk factors such as alcohol intake, smoking status, physical activity, and even BMI, which may be on the causal pathway.

Overall, these studies suggest that regular consumption of breakfast, and in particular food items such as whole grains, ready-to-eat breakfast cereal, and fruits, may be protective against the onset of chronic disease risk, morbidity, and mortality. Although many observational studies document an independent association between healthful breakfast eating habits and reduced risk for chronic disease, randomized clinical trials are the definitive study design to examine causality and are discussed below.

Table 4. Prospective Studies of Breakfast Habits and Chronic Disease Risk in Adults

Author/Year	Sample	Study Title	Variable Measured	Results
Kaplan et al., 1987[108]	Elderly adults (4174 M/W)	Alameda County Study	Seven risk factors (including regular breakfast consumption) via a questionnaire about behavioral, social, and psychological aspects	Increased risk of 17-y mortality (RR 1.46, CI 1.17 to 1.83) in subjects > 60 years of age; RR 1.35, 95% CI 1.08 to 1.70 when all seven risk factors included in model
Liu et al., 2003[109]	Normal-weight adults (86,190 M)	Physicians' Health Study	Breakfast cereal (whole, refined, and total grain) intake measured (via a semiquantitative food frequency questionnaire) and mortality	Graded inverse relation of whole-grain breakfast cereal intake to total mortality (RR 0.73, 95% CI 0.65 to 0.82), CVD mortality (RR 0.72, 95% CI 0.61 to 0.85), and MI mortality (RR 0.77, 95% CI 0.57 to 1.01)

CI, confidence interval; CVD, cardiovascular disease; MI, myocardial infarction; RR, relative risk.

RANDOMIZED TRIALS OF BREAKFAST HABITS, BODY WEIGHT, AND DISEASE RISK FACTORS

Four randomized trials on breakfast habits, body weight, or chronic disease risk factors have been conducted to date (Table 5).[13,85,93,110] In one study, 52 moderately obese adult women were stratified according to baseline breakfast-eating habits and randomly assigned to one of two treatments: no breakfast (two meals per day) or breakfast (three meals per day).[93] After 12 weeks, an interaction between baseline breakfast habits and treatment assignment was suggested ($P = 0.06$), with baseline breakfast skippers losing 7.7 kg in the breakfast treatment and 6.0 kg in the no-breakfast treatment. However, the opposite effect was observed in those who consumed breakfast at baseline, with a loss of 8.9 kg in the no breakfast treatment and 6.2 kg in the breakfast treatment, leaving in question whether breakfast may have an important causal role in body weight regulation.

In a small clinical trial, 10 moderately obese women consumed 70% of their daily energy intake either in the AM (35% consumed at breakfast and lunch) or the PM (35% consumed at dinner and the evening snack).[110] Loss of body weight and fat-free mass was significantly greater with the consumption of the AM diet pattern ($P < 0.01$ and $P < 0.001$, respectively), but maintenance of fat-free mass was greater with the PM diet pattern, suggesting that the consumption of larger PM meals

Table 5. Randomized Trials of Breakfast Habits, Body Weight, and Disease Risk Factors

Author/Year	Sample	Design	Duration	Intervention	Results
Schlundt et al., 1992[93]	Obese adults (52 F)	Two-treatment crossover	12 wks each	Energy intake fixed: 2 meals (omit breakfast) vs. 3 meals (eat breakfast)	Baseline breakfast skippers lost 6.0 ± 3.9 kg in omit-breakfast treatment and 7.7 ± 3.3 kg in eat-breakfast treatment ($P < 0.06$); baseline breakfast eaters lost 8.9 ± 4.2 kg in omit-breakfast treatment and 6.2 ± 3.3 kg in eat-breakfast treatment ($P < 0.06$)
Keim et al, 1997[110]	Obese adults (10 F)	Two-treatment crossover	6 wks each	Energy intake fixed: 70% of daily energy intake in 2 largest meals (35% each) in AM vs. PM	Large AM meals led to greater loss of body weight and fat-free mass ($P < 0.01$); period effect (1 vs. 2) showed greater loss of body weight and fat mass ($P < 0.05$) and less loss of fat-free mass ($P < 0.05$) during period 1
Kleemola et al., 1999[85]	Normal-weight adults (209 M/F)	Two-treatment crossover with washout	6 wks each	Eat breakfast (intervention) vs. usual habits (no intervention)	Breakfast treatment led to 5.5% reduction in total dietary fat, 2.5% in saturated dietary fat ($P = 0.0001$); 2.5% reduction in total serum cholesterol with breakfast treatment; no significant change in body weight in breakfast treatment or control ($P = 0.16$)
Farshchi et al., 2005[13]	Normal-weight adults (10 F)	Two-treatment crossover with washout	14 d each	Energy intake fixed: omit breakfast vs. eat breakfast	Reduced energy intake with eat-breakfast treatment; significantly decreased insulin AUC, $P = 0.001$; significantly increased fasting total cholesterol ($P = 0.02$) and LDL-cholesterol ($P = 0.04$) with omit-breakfast treatment; no significant change in body weight in either treatment group

AUC, area-under-the curve; LDL, low-density lipoprotein.

during weight loss may be important in minimizing the loss of muscle mass.

In a larger randomized, crossover trial, 209 men and women either consumed 80 g (men) and 60 g (women) of cereal at breakfast or continued their usual dietary habits (no breakfast intervention) to serve as controls.[85] Two refined grain cereals were provided for the intervention (Cornflakes or Rice Krispies®) and were eaten during the breakfast meal. For the remainder of each day, subjects were instructed to follow their usual eating habits. Data from 3-day food records documented reductions in total and saturated fatty acids during the breakfast intervention ($P < 0.0001$), but no significant change in body weight was observed, presumably because the increase in carbohydrate intake was calorically equivalent to the reduction in dietary fat. The reduction in dietary saturated fat intake led to a modest (0.15 mM/L, $P = 0.007$) reduction in serum cholesterol.

Lastly, the effect of omitting breakfast on insulin sensitivity and lipid profiles has been documented.[13] Ten healthy women consumed two different diets for 14 days each, with a 14-day washout period. The diet included breakfast consisting of 45 g of whole-grain cereal (Bran Flakes®) with 2% milk before 8:00 AM and a cookie between 10:30 and 11:00 AM. When breakfast was omitted, subjects consumed the cookie between 10:30 and 11:00 AM and the cereal and milk between 12:00 and 1:30 PM. When breakfast was omitted, significantly higher fasting total cholesterol (3.43 ± 0.44 vs. 3.14 ± 0.41 mM/L, $P = 0.001$) and LDL cholesterol (1.82 ± 0.30 vs. 1.55 ± 0.28 mM/L, $P = 0.001$) concentrations were observed. Furthermore, the insulin area-under-the curve after a test meal was significantly reduced after the breakfast eating period ($P = 0.04$), but appeared to increase after the breakfast skipping period ($P = 0.06$). Additional data also found mean energy intake to be significantly lower when breakfast was consumed compared with when it was omitted (6.97 ± 0.59 vs. 7.35 ± 0.65 mJ/d, $P = 0.001$). These authors suggested that omitting breakfast impairs fasting lipids and postprandial insulin sensitivity and may lead to weight gain over a longer period of time if the effect on energy intake were maintained.

Results from these few, small, short-term randomized trials of breakfast behavior provide mixed results, but do provide some support for the hypothesis that the regular consumption of a breakfast meal may reduce the risk of obesity and chronic disease. Only more definitive, larger, and longer randomized, controlled trials will provide clear answers to these important public health questions regarding the link between dietary behaviors, dietary composition, and risk of obesity and related chronic diseases.

CONCLUSIONS

Breakfast consumption is independently associated with a lower BMI in adults in a number of cross-sectional studies. Only two prospective studies and four randomized trials were found to date, and the results from these are inconsistent. Although the precise mechanisms are unclear, breakfast eating may prevent obesity and related chronic conditions through a number of behavioral and biological mechanisms, including being part of an overall healthful eating pattern, improving the composition of the diet, and, through a variety of substrate/metabolic pathways, aiding in appetite control throughout the day.

Future studies on this topic should further address these potential mechanisms, as well as a number of important issues that likely require better-designed randomized trials. It may be important to distinguish between promoting breakfast consumption versus promoting a healthful breakfast (i.e., whole grains, fruits), as diets including nutrient- and fiber-rich carbohydrates have been shown to lead to weight loss and reduce disease risk. Measurement of breakfast frequency for the most part is self-reported and subject to each individual's idea of what constitutes breakfast. Thus, it is possible that the lack of a universal definition for breakfast and measurement of the breakfast meal has led to conflicting results in some cross-sectional and prospective studies assessing the association between breakfast and obesity and chronic disease risk.

The issue of confounding also deserves discussion. Breakfast consumption in itself has the potential to directly affect dietary quality through the foods eaten at this meal. However, breakfast consumption may also act indirectly in that healthy food behaviors (i.e., increased vegetable intake) tend to cluster together. Additionally, other health-related behaviors associated with healthy eating (i.e., reduced smoking and alcohol consumption, increased physical activity) may have further affected the results observed. What effect these issues may have had on the studies discussed herein is not always clear.

To date, the randomized trials on this topic have been limited in size and scope, likely undermining their ability to clearly address the potential breakfast frequency and/or quality and body weight link. Therefore, larger and longer trials will be needed and should include a standardized definition of breakfast. To further refine any causal link between breakfast consumption and risk for obesity, delineation between whole- and refined-grain cereal consumption will be helpful, as well as other aspects of breakfast quality including other types of grains or dairy and fruit products.

As a large percentage of the adult US population currently skips breakfast, the impact of regular breakfast

consumption on public health may be significant. If future trials support this possibility, more emphasis should be placed on breakfast habits, especially during young adulthood, when behavioral patterns are developing and stabilizing.

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