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BREAKFAST AND READY-TO-EAT CEREAL CONSUMPTION ARE ASSOCIATED WITH IMPROVED MARKERS OF CARDIOMETABOLIC HEALTH IN ADULTS: RESULTS FROM THE NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY 2001 - 2008

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Abstract: *Background:* Breakfast and cereal consumption has been associated with higher diet quality, lower body weight and improved measures of cardiometabolic health. *Objectives:* To investigate the relationship between breakfast consumption, particularly ready-to-eat cereal, and anthropometric measures, likelihood of overweight/obesity, prevalence of metabolic syndrome (MetS), and other cardiometabolic risk factors in US adults. *Design:* Cross-sectional. *Setting:* The 2001-2008 National Health and Nutrition Examination Survey (NHANES), USA. *Participants:* Adults aged 19-70 years (n=14,316) divided into 2 groups: 19-50 years (n=9,292) and 51-70 years (n=5,024). *Measurements:* Three breakfast types were defined, ready-to-eat cereal (RTEC), Other Breakfast (OB) and No Breakfast (NB) using a 24 hour dietary recall. Sample weighted data were used to determine least square means ± SE by regression analysis with adjustment for covariates. Odds ratios for risk factors were determined by logistic regression with adjustment for covariates. *Results:* RTEC and OB consumption were associated with more favorable anthropometry, cardiometabolic measures, and lower prevalence of risk factors for MetS compared to NB in 19 to 50 year old adults. RTEC consumption, compared to OB, was associated with lower body weight, lower BMI, reduced abdominal adiposity and lower prevalence of risk factors for MetS in adults aged 19 to 50 years. There were no differences in likelihood of being overweight or obese or the presence of risk factors for MetS in the 51 to 70 year old adults based on breakfast type. *Conclusion:* Consumption of breakfast, particularly RTEC, may contribute to healthy aging through reduced risk of chronic disease.

Key words: NHANES, breakfast, ready to eat cereal (RTEC), cardiometabolic risk, metabolic syndrome.

Introduction

The 2010 Dietary Guidelines for Americans (DGA 2010) include a recommendation to "eat a nutrient-dense breakfast" and state that consuming breakfast is associated with "weight loss and weight loss maintenance, as well as improved nutrient intake" (1). Previous research found that skipping breakfast has a negative impact on several measures of cardiometabolic health which may contribute to chronic disease (2, 3). Breakfast that includes ready-to-eat cereal (RTEC) has been associated with higher diet quality, (4, 5) lower body weight, and body mass index (BMI) in children and adults (6-10).

Metabolic syndrome (MetS) is a group of inter-related factors that increases risk of both cardiovascular disease (CVD) and type 2 diabetes. MetS risk factors defined by the National Cholesterol Education Program (NCEP) Adult Treatment Panel (ATP III) include abdominal obesity, atherogenic dyslipidemia, elevated blood pressure, and elevated plasma glucose (11). The American Heart Association estimates that approximately 34% of US adults age 20 years and over meet the definition for MetS (12). Lifestyle intervention with weight loss, dietary changes and increased physical activity are currently the recommended intervention to reduce risk of MetS (13). Dietary patterns emphasizing cereal fiber, whole grains, fish, fruits, vegetables and legumes have been associated with reduced risk of MetS (14-19). Young adult RTEC consumers were significantly less likely to be overweight/obese or have risk factors for MetS (10). Lifestyle factors that favorably impact cardiometabolic risk factors can reduce risk of chronic disease and contribute to healthy aging.

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The objective of this study was to investigate the relationship between breakfast consumption, particularly ready-to-eat cereal, and anthropometric measures, likelihood of overweight/obesity, prevalence of MetS, and other cardiometabolic risk factors in US adults using 2001 to 2008 National Health and Nutrition Examination Survey (NHANES) data.

Methods

Data Collection

The continuous NHANES is a cross-sectional survey that collects data pertaining to the nutrition and health status of the US population using a complex, multi-stage, probability sampling design. Data are released in two year increments and for this secondary analysis the data sets from 2001-2002, 2003-2004, 2005-2006 and 2007-2008 were combined to increase sample size. Detailed information about the NHANES design, procedures and methodologies can be found on the National Center for Health Statistics web site (20). Trained interviewers conducted 24-hour dietary recalls using an automated multiple pass data collection method (21, 22). In the combined NHANES 2001-2008, after excluding pregnant and/or lactating females, there were 14,316 participants aged 19 to 70 years whose dietary records were considered complete and reliable by the USDA Food Surveys Research Group who collected the NHANES 24-hour recall data. Day 1 dietary data were used to determine whether breakfast consumption for each subject was RTEC (food codes beginning with 571, 572, 573 or 574), Other Breakfast (OB, any food consumed for breakfast that was not RTEC) or No Breakfast (NB, subjects who did not report consuming any breakfast other than water). Breakfast for each subject was self defined. Participants were divided into two age groups for analyses: adults 19 to 50 years of age (n=9,292) and adults 51 to 70 years of age (n=5,024).

Physical examinations included measurements of standing height, weight and waist circumference (WC) and were obtained by trained staff in mobile examination centers according to NHANES protocols (23). Body mass index (BMI) values were calculated as body weight (kilograms) divided by height (meters) squared. Overweight was defined as a BMI value greater than or equal to 25 kg/m^2 and less than 30 kg/m^2 and obesity was defined as a BMI greater than or equal to 30 kg/m^2 (24). Blood pressure and laboratory values for serum lipids and other cardiovascular risk factors were determined according to NHANES protocols. Clinical identification of metabolic syndrome was based on the presence of three or more risk factors or use of drugs to address risk factors identified by the National Cholesterol Education Program (NCEP) Adult Treatment Panel (ATP III) (11).

This secondary analysis of publically available NHANES data lacked personal identifiers and was exempt from institutional review board review.

Statistical Analysis

Sample-weighted data were used in all statistical analyses, and all analyses were performed using SUDAAN Release 10.0.1 (Research Triangle Institute, Research Triangle Park, NC) to adjust variances for the clustered sample design. Eight year mobile exam center (MEC) weights were calculated and used for these analyses and for certain variables eight year fasting sample weights were used (i.e. glucose, triglycerides, LDL-cholesterol (LDL-C) and apolipoprotein-B (Apo-B) (25). Regression analysis provided adjusted least square means, prevalence rate, standard errors of the mean, and p-values across breakfast consumption groups. Logistic regression was used to determine the likelihood (odds ratios) of being overweight or obese or having increased odds ratios for increased waist circumference, elevated blood pressure (systolic ≥ 130 mmHg or taking antihypertensive medication), high LDL-C (≥ 100 mg/dL or taking medication to address), low high-density-cholesterol (HDL-C)(≤ 40 mg/dL in men or ≤ 50 mg/dL in women or taking medication to address), high fasting triglycerides (≥ 150 mg/dL or taking medication to address), high fasting glucose (≥ 100 mg/dL or taking medication to address) and MetS (defined as ≥ 3 of 5 NCEP ATPIII risk factors) (11). Analyses were conducted separately for adults 19 to 50 years and 51 to 70 years. Covariates used in regression and logistic regression analysis were age (years), ethnicity, poverty income ratio (PIR), energy (Calories), physical activity (sedentary, moderate or active based on questionnaire), smoker status (current smoker versus non-smoker), alcohol consumption (g/d) and BMI. BMI was not used when the dependent variable was body weight, waist circumference, or any associated risk variable. Statistical significance was set at $p < 0.05$.

Results

Breakfast consumption (RTEC and OB) was associated with lower body weight, lower BMI, and lower waist circumference compared to NB among 19 to 50 year old adults (Table 1). Furthermore, compared to OB, RTEC consumption was associated with lower body weight, lower BMI and lower waist circumference. There were no significant differences among RTEC, OB and NB for blood pressure, triglycerides, and apolipoprotein-B (Apo-B). However, RTEC consumption, but not OB, was associated with lower plasma glucose and LDL-C compared to NB. OB consumption was associated with a higher HDL-C compared to NB but not compared to RTEC.

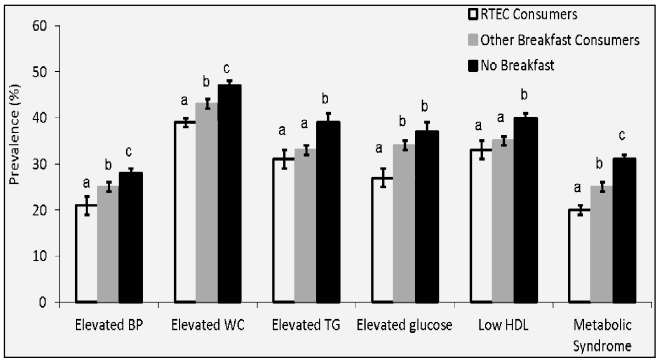
Table 1
Cardiometabolic measurements based on breakfast consumption and type for 19 – 50 year old adults[1]

Measurement	RTEC n=1,148	Other Breakfast n-5,700	No Breakfast n=2,444
BW (kg)	79.07 (0.62)[a]	81.37 (0.45)[b]	83.70 (0.63)[c]
BMI (kg/m²)	27.19 (0.20)[a]	27.95 (0.15)[b]	28.77 (0.21)[c]
SBP (mmHg)	117 (0.42)	117 (0.28)	118 (0.35)
DBP (mmHg)	72 (0.35)	72 (0.25)	72 (0.30)
WC (cm)	93.12 (0.50)[a]	94.75 (0.37)[b]	96.53 (0.43)[c]
TG (mg/dL)	132.97 (4.81)	133.53 (3.55)	142.25 (4.03)
Glucose (mg/dL)	96.79 (0.63)[a]	98.26 (0.46)[ab]	98.68 (0.68)[b]
HDL-C (mg/dL)	50.78 (0.52)[ab]	51.69 (0.28)[a]	50.68 (0.36)[b]
LDL-C (mg/dL)	110.83 (1.84)[a]	114.24 (0.76)[ab]	116.77 (1.39)[b]
Apo-B (mg/dL)	92.51 (2.03)	94.01 (0.94)	95.06 (1.03)

1. Data are least square means (SEM) from sample weighted analyses adjusting for the complex sample design of NHANES and included the following as covariates: age, ethnicity, poverty income ration (PIR), energy (Calories), physical activity, smoker status, alcohol consumption and BMI (BMI not used with BW, WC or BMI). For each row, means with different superscript letters are significantly different (p<0.05). BW=body weight, SBP=systolic blood pressure, DBP diastolic WC=waist circumference, TG=triglyceride, Apo-B = Apolipoprotein B

As shown in Figure 1, both RTEC and OB consumers had a lower prevalence of elevated blood pressure, elevated waist circumference, elevated triglycerides, low HDL-C, and MetS compared to NB. However, compared to OB, RTEC consumers had a lower prevalence of elevated blood pressure, elevated waist circumference, elevated plasma glucose, and MetS.

Figure 1
Prevalence of NCEP ATPIII risk factors for MetS based on breakfast consumption and type for 19 – 50 year old adults[1]



1. Data are means ± SEM from sample weighted analyses adjusting for the complex sample design of NHANES and included the following as covariates: age, ethnicity, poverty income ratio (PIR), energy (Calories), physical activity, smoker status, alcohol consumption and BMI (BMI not used with WC). For each measurement, bars with different letters are significantly different. Elevated BP systolic ≥ 130 mmHg or diastolic ≥ 85 mmHg or meds. Elevated WC ≥ 102 cm (♂) ≥ 88 cm (♀). Elevated TG ≥ 150 mg/dL or meds. Elevated glucose ≥ 100 mg/dL. Low HDL ≤ 40 mg/dL (♂) ≤ 50 mg/dL (♀). Metabolic syndrome is ≥ 3 of 5 NCEP ATPIII risk factors

Compared to NB, RTEC and OB consumers were 33 and 15% less likely to be overweight or obese, or have elevated blood pressure, elevated waist circumference, elevated triglycerides, low HDL-C, and MetS (Table 2). In addition, RTEC, but not OB consumers, were less likely to have elevated glucose compared to NB.

Table 2
Odds ratios for overweight/obesity and NCEP ATP III risk factors for metabolic syndrome based on breakfast type for 19 – 50 year old adults[1]

Risk Factor	RTEC	p value	Other Breakfast	p value
Overweight or Obese	0.67 (0.55-0.81)	0.0001	0.85 (0.73-0.99)	0.0360
Elevated BP	0.64 (0.050-0.82)	0.0007	0.80 (0.68-0.95)	0.0124
Elevated WC	0.68 (0.56-0.83)	0.0003	0.82 (0.70-0.96)	0.0142
Elevated Triglycerides	0.69 (0.52-0.93)	0.0140	0.76 (0.62-0.94)	0.0116
Elevated Glucose	0.57 (0.43-0.77)	0.0003	0.85 (0.71-1.01)	0.0691
Low HDL-C	0.75 (0.59-0.95)	0.0196	0.81 (0.70-0.93)	0.0046
Metabolic Syndrome	0.50 (0.40-0.64)	0.0001	0.70 (0.58-0.85)	0.0005

1. Data are odds ratios and lower to upper 95th percentile confidence levels compared to No Breakfast group from sample weighted analyses adjusting for the complex sample design of NHANES and included the following as covariates: age, ethnicity, poverty income ratio (PIR), energy (Calories), physical activity, smoker status, alcohol consumption and BMI (BMI not used with overweight, obese or WC). Elevated BP systolic ≥ 130 mmHg or diastolic ≥ 85 mmHg or meds. Elevated WC ≥ 102 cm (♂) ≥ 88 cm (♀). Elevated TG ≥ 150 mg/dL or meds. Elevated glucose ≥ 100 mg/dL. Low HDL ≤ 40 mg/dL (♂) ≤ 50 mg/dL (♀). Metabolic syndrome is ≥ 3 of 5 NCEP ATPIII risk factors

There were no differences in cardiometabolic measurements based on breakfast consumption or breakfast type for the 51 to 70 year old adults except for triglycerides and plasma glucose (Table 3). NB was associated with a higher triglyceride measurement compared to OB consumers. RTEC consumption was associated with a lower HDL-C measurement compared to OB; however, all breakfast groups had HDL-C measurements ≥ 50 mg/dL. There were no differences in likelihood of being overweight or obese or the presence of risk factors for MetS in the 51 to 70 year old adults based on breakfast type (Table 4).

Table 3
Cardiometabolic measurements based on breakfast consumption and type for 51-70 year old adults[1]

Measurement	RTEC n=848	Other Breakfast n=3,473	No Breakfast n=703
BW (kg)	83.73 (0.87)	83.31 (0.51)	82.79 (1.07)
BMI (kg/m²)	29.16 (0.31)	29.25 (0.17)	29.02 (0.35)
SBP (mmHg)	129 (0.8)	129 (0.17)	128 (0.1)
DBP (mmHg)	74 (0.4)	74 (0.3)	74 (0.8)
WC (cm)	101.1 (0.8)	101.2 (0.4)	100.9 (0.7)
TG (mg/dL)	160.1 (5.7)[ab]	154.5 (3.5)[a]	210.6 (28)[b]
Glucose (mg/dL)	109.1 (2.0)	110.4 (1.14)	113.1 (3.5)
HDL-C (mg/dL0	53.0 (0.6)[a]	54.6 (0.3)[b]	54.2 (0.9)[ab]
LDL-C (mg/dL)	120.8 (1.9)	124.4 (1.2)	128.6 (3.8)
Apo-B (mg/dL)	101.2 (2.1)	103.2 (1.4)	104.7 (3.4)

1. Data are least square means (SEM) from sample weighted analyses adjusting for the complex sample design of NHANES and included the following as covariates: age, ethnicity, poverty income ration (PIR), energy (Calories), physical activity, smoker status, alcohol consumption and BMI (BMI not used with BW, WC or BMI). For each row, means with different superscripts are significantly different (p<0.05). BW=body weight, SBP=systolic blood pressure, DBP=diastolic blood pressure, WC=waist circumference, TG=triglyceride, Apo-B = Apolipoprotein B

Table 4
Odds ratios for overweight/obesity and NCEP ATP III risk factors for metabolic syndrome based in breakfast type for 51 -70 year old adults[1]

Risk Factor	RTEC	p value	Other Breakfast	p value
Overweight or Obese	0.96 (0.67-1.37)	NS	0.98 (0.76-1.27)	NS
Elevated BP	1.12 (0.81-1.56)	NS	1.22 (0.95-1.57)	NS
Elevated WC	0.89 (0.65-1.22)	NS	0.97 (0.78-1.21)	NS
Elevated Triglycerides	0.90 (0.59-1.36)	NS	0.95 (0.68-1.33)	NS
Elevated Glucose	0.69 (0.44-1.08)	NS	0.83 (0.55-1.25)	NS
Low HDL-C	1.04 (0.79-1.37)	NS	1.02 (0.77-1.33)	NS
Metabolic Syndrome	0.96 (0.68-1.36)	NS	1.07 (0.76-1.49)	NS

1. Data are odds ratios and lower to upper 95th percentile confidence levels compared to No Breakfast group from sample weighted analyses adjusting for the complex sample design of NHANES and included the following as covariates: age, ethnicity, poverty income ratio (PIR), energy (Calories), physical activity, smoker status, alcohol consumption and BMI (BMI not used with overweight, obese or WC). Elevated BP systolic ≥ 130 mmHg or diastolic ≥ 85 mmHg or meds. Elevated WC ≥ 102 cm (♂) ≥ 88 cm (♀). Elevated TG ≥ 150 mg/dL or meds. Elevated glucose ≥ 100 mg/dL. Low HDL ≤ 40 mg/dL (♂) ≤ 50 mg/dL (♀). Metabolic syndrome is ≥ 3 of 5 NCEP ATPIII risk factors

Discussion

Breakfast and RTEC consumption, compared to NB, was associated with more favorable anthropometric and cardiometabolic measures and lower prevalence of risk factors for MetS in 19 to 50 year old adults. Furthermore, RTEC consumption, compared to OB, was associated with lower body weight, lower BMI, reduced abdominal adiposity, and lower prevalence of risk factors for MetS in adults aged 19 to 50 years.

This report confirms previous findings that both breakfast and RTEC consumption are associated with lower body weight and/or BMI (3, 6-10, 26). Previous analyses of NHANES data reported inverse associations between breakfast consumption and BMI (10, 26) and RTEC consumption and BMI or body weight (7, 8, 10). Consumption of over one serving per day of either whole grain or refined grain RTEC reduced the risk of being overweight by 22% at eight years and by 12% at 13 years of follow-up in men (9). Seventy-eight percent of National Weight Control Registry subjects reported regularly eating breakfast (27). Larger waist circumference has been reported in adults who skipped breakfast (3). RTEC may have beneficial effects on body weight and waist circumference independent of consumption at breakfast. Overweight adults who consumed RTEC as an evening snack had reductions in both body weight and waist circumference after six weeks (28).

RTEC consumption was associated with the lowest prevalence and risk of MetS compared to OB and NB in this study. Both RTEC and OB consumption were associated with lower prevalence and reduced risk of several NCEP ATP III risk factors and MetS compared to NB in 19 to 50 year old adults. However, RTEC consistently demonstrated a lower prevalence and odds ratio for most NCEP ATP III risk factors compared to OB.

Few other population studies have investigated the association of breakfast consumption and MetS. Higher breakfast food scores (based on the amounts of selected foods) for intakes of typical Italian breakfast foods, including cereals, were associated with lower prevalence of MetS in adults 35 years and older (29). Young adult breakfast and RTEC consumers in the US had lower prevalence of the individual risk factors for MetS; however no association was found between breakfast skipping or type of breakfast and the prevalence of MetS (10). Other studies have found omitting breakfast was associated with higher fasting insulin, total and LDL cholesterol compared to breakfast consumers (2, 3, 10). One intervention study found breakfast cereal consumption for six weeks resulted in a 2.5% reduction in total cholesterol in healthy adults (30).

One potential explanation for beneficial effects of RTEC consumption on cardiometabolic risk factors is that RTEC is a contributor of cereal fiber and whole grain to the diet. Cereal fiber was inversely associated with the risk of MetS in a cross-sectional survey of adults (18). Cereal fiber intake has also been associated with lower BMI, waist circumference and serum total cholesterol in adults (31). Minimally processed cereals have been associated with decreased risk of MetS (32). Whole grain consumption has been associated with lower mean BMI and waist circumference (33) and a lower prevalence of MetS (18).

Breakfast consumption may have a greater impact on cardiometabolic measures in younger adults than older adults. With the exception of triglyceride and HDL-C measurements, there were no differences in cardiometabolic measurements, likelihood of being overweight/obese, or the presence of risk factors for MetS in the 51 to 70 year old adults based on breakfast type. Factors contributing to the different impact of breakfast consumption on measures of cardiometabolic health between younger and older adults are not clear. The cardiometabolic measures in older adults were consistently higher than younger adults, which could prevent modest effects of diet from being observed. Additionally, older adults may be more likely than younger adults to use antihypertensive or cholesterol lowering medications so diet may have less of an impact on measurements. In contrast to this study, Deshmukh-Taskar et al (10) reported no difference in the prevalence of MetS by breakfast skipping or type of breakfast in young adults 20 to 39 years; older adults were not studied. Sahyoun et al (19) reported an inverse trend for whole grain intake, prevalence of MetS and CVD mortality in 60 to 98 year old adults. Cereal fiber was also inversely associated with BMI and abdominal obesity in adults aged 60 to 80 years (34).

There are a number of physiological mechanisms through which breakfast consumption may have a positive impact on body weight and risk factors for

chronic disease. Breakfast consumption may contribute to appetite control and have a favorable impact on glucose and lipid metabolism (35). Regular breakfast consumers have higher diet quality compared to breakfast skippers. Intakes of fiber and other nutrients is higher and energy density is lower among breakfast consumers (4, 5, 35, 36). RTEC consumers have been reported to have higher nutrient intakes compared to consumers of other breakfasts (4, 5).

This study has several limitations. The cross-sectional design of NHANES does not allow causal inferences or measures in the same individual over time. Also, a single 24-hour dietary recall may not reflect the usual dietary pattern of participants. However, NHANES is a large observational study of a nationally representative sample of the US population that allows the assessment of numerous outcomes. The age stratifications used in this study were set based on the Institute of Medicine Dietary Reference Intakes report age groupings (38). A different age stratification as some others have used (19, 34) may have yielded different results. The other breakfast category is not well defined, yet still shows a benefit over no breakfast for many cardiometabolic measures. Further study into the other breakfast category may reveal dietary factors similar to that in RTEC (e.g. high fiber hot cereals or breakfast bars) which may give insight into these effects.

In conclusion, consumption of RTEC and OB was associated with reduced likelihood of overweight/obesity and reduced prevalence and risk for MetS compared to NB in 19 to 50 year old adults. RTEC breakfast consumption showed particular benefit over OB for a number of metabolic risk factors as well as reduced prevalence and risk for MetS. Consumption of breakfast, particularly RTEC, may contribute to healthy aging through reduced risk of chronic disease.

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