NATIONAL PATTERNS OF BREAKFAST CONSUMPTION: NUTRITIONAL AND HEALTH IMPLICATIONS

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

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COLLEGE OF HEALTH SCIENCES

BY

PRIYA DESHMUKH-TASKAR, M.Sc., M.S.

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To the Dean of the Graduate School:

I am submitting herewith a dissertation written by Priya Deshmukh-Taskar entitled "National Patterns of Breakfast Consumption: Nutritional and Health Implications." I have examined this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy with a major in Nutrition.

Dr. John Radcliffe, Major Professor

We have read this dissertation and recommend its acceptance:

Department Chair

Accepted:

Dean of the Graduate School

DEDICATION

I would like to dedicate this dissertation to my dear son, Eshan, who was my tremendous source of inspiration throughout the research process. His kind little words, 'I LOVE YOU MUMMY' and 'DON'T BOTHER MUMMY' when I had those 'frustrating' moments, would put a smile on my face and keep me motivated to achieve my goal. He was also very considerate throughout the process, even on those moments when I was not able to give him my full attention; he would console himself by saying 'MUMMY HAS TO STUDY NOW'. Eshan, this dissertation is for you!

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ABSTRACT

PRIYA DESHMUKH-TASKAR

NATIONAL PATTERNS OF BREAKFAST CONSUMPTION:
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The nutritional and health implications of breakfast skipping and type of breakfast consumed were assessed in children (9-13 years, n=4,320), adolescents (14-18 years, n=5,339), and young adults (19-39 years, n=5,316) via three studies. Cross-sectional datasets from the National Health and Nutrition Examination Survey (1999-2006) were used. A 24-hour dietary recall was used to assess self-reported breakfast/brunch consumption, nutrient intakes, nutrient adequacy, and diet quality (i.e., mean adequacy ratio [MAR] and Healthy Eating Index [HEI] scores respectively). Occurrence(s) of overweight/obesity (among all), and the metabolic syndrome (MetS) and its related risk factors (among young adults) were examined using anthropometric and laboratory measurements. Covariate-adjusted sample-weighted means were compared using analysis of variance (with Bonferroni's correction) between breakfast skippers (BS), ready-to-eat cereal (RTEC) breakfast consumers, and other breakfast (OB) consumers. Associations between breakfast consumption, overweight/obesity, and risk factors for MetS were determined using covariate-adjusted multinomial logistic regression. Results revealed that 20.1% children, 31.5% adolescents, and 25.1% young adults were BS; 35.9%

children, 25.4% adolescents, and 16.5% young adults were RTEC consumers. Among all ages, compared to BS and OB consumers, the mean percent energy intakes from total fat were lower and carbohydrate were higher among RTEC consumers. Among all ages, compared to BS and OB consumers, RTEC consumers had higher mean intakes of dietary fiber and several micronutrients, and had lower mean intakes of cholesterol. Among all ages, the MAR for micronutrients was highest in RTEC consumers and lowest in BS. In children/adolescents, BS had a higher mean waist circumference (i.e., abdominal obesity) than RTEC and OB consumers. Overall obesity occurrence was higher in BS than RTEC consumers in children/adolescents and was higher in OB than RTEC consumers in adolescents. Among young adults, compared to BS and OB consumers, the mean total HEI score and its several component scores (for the intakes of whole fruits, whole grains, milk, and discretionary calories) were higher among RTEC consumers. Among young adults, compared to BS and OB consumers, the mean values for body mass index, waist circumference (i.e., abdominal obesity), and triceps skinfold measurement were all lower among RTEC consumers. In young adults, compared to BS, RTEC consumers had lower mean serum total and low-density lipoprotein cholesterol concentrations and insulin resistance. Relative to BS and OB consumers, young adults who consumed RTEC had lower odds of being overweight/obese, having abdominal obesity, and hyperhomocysteinemia. Thus, compared to BS and OB consumers, RTEC consumers had better nutrient intakes/adequacy and diet quality, as well as lower adiposity measures and serum/plasma metabolic risk factors.

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CHAPTER I

INTRODUCTION

Breakfast is traditionally considered as the most important meal of the day, although there is ample scientific evidence suggesting the nutritional benefits of breakfast consumption. The body (especially, the brain) needs a metabolic substrate in the form of carbohydrate and amino acids to function optimally after an overnight fast (Wurtman et al., 2003). Regular omission of breakfast leads to a decreased intake of several nutrients from the diet. Previously, consumption of breakfast has been associated with higher intakes of energy, macronutrients, and several micronutrients, such as B vitamins (including folate), and calcium (Nicklas, Myers, Reger, Beech, & Berenson, 1998; Nicklas, Reger, Myers, & O'Neil, 2000). Besides nutritional benefits, several other health benefits of breakfast consumption have been proposed (see Figure 1). For example, breakfast consumption has been associated with having a lower body mass index (BMI) in children/adolescents (Affenito et al., 2005; Albertson, Anderson, Crockett, & Goebel, 2003; Barton et al., 2005) as well as in adults (Cho, Dietrich, Brown, Clark, & Block, 2003; Mattes, 2002; Song, Chun, Obayashi, Cho, & Chung, 2005; Wyatt et al., 2002). Additionally, breakfast consumption has been linked with improved cognitive performance, memory, alertness, and mood in children adolescents (Ingwersen, Defeyter, Kennedy, Wesnes, & Scholey, 2007). Yet, several purported benefits of breakfast consumption are not fully scrutinized in today's research. For example, whether

breakfast consumption affects diet quality, satiety, eating habits, and the occurrence of metabolic disorders is not understood (see Figure 1).

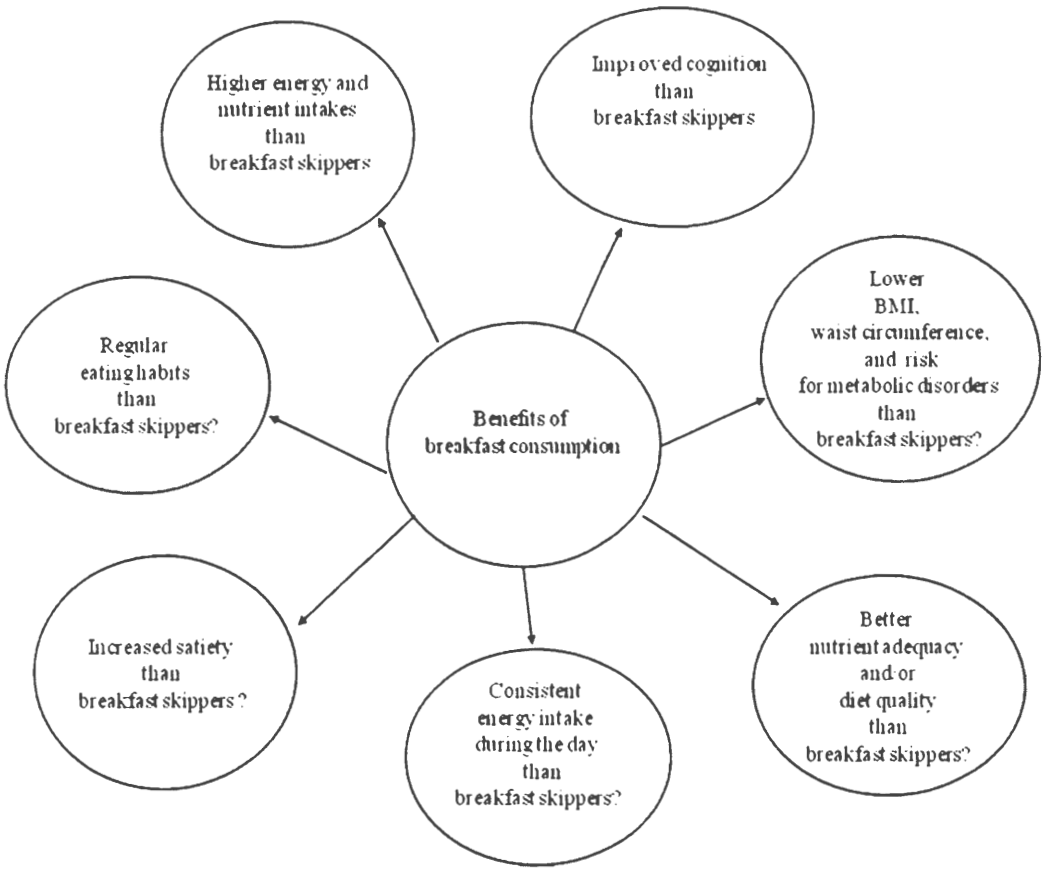

Figure 1. Benefits of breakfast consumption. *Note.* BMI = body mass index

Problem Statement(s)

Despite the benefits, breakfast consumption tends to decline with increasing age until young adulthood (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2001-2002; Lake, Mathers, Rugg-Cunn, & Adamson, 2006). In the United States (US), skipping of breakfast is mainly prevalent among younger age groups, i.e., children/adolescents (9-18 years of age/year old [y]), and young adults (20-39 y). In a previous national survey, it was noted that in the year 1965, 5% of 11-14 y and 12% 15-18 y children/adolescents skipped breakfast, increasing in 1991 to 20% and 30% respectively (Seiga-Riz, Popkin, & Carson, 1998). One strategy to reduce the prevalence of breakfast skipping was the introduction of the National School Breakfast Program introduced in 1966 (Food Research and Action Center, 2005), which provides children/adolescents with >25% of the Recommended Dietary Allowance (RDA) for several key nutrients at breakfast (e.g., proteins, calcium, and iron) (Kenedy & Davis, 1998; Food Research and Action Center; United States Department of Agriculture, School Breakfast Program, 1969-2009). Although the School Breakfast Program has been beneficial in reducing the prevalence of breakfast skipping and providing nutritious breakfast meals at school to many children/adolescents (Food Research and Action Center; Kenedy & Davis, 1998), not all schools participate in this program. The 1999-2000 National Health and Nutrition Examination Survey (NHANES) statistics showed that the prevalence of breakfast skipping increased from the past figures in children (9-13 y) to 20.5% and in adolescents (14-18 y) to 36.1% (Song et al., 2006).

Moreover, the habit of breakfast skipping if not corrected in the early years of life may tend to persist even during young adulthood. In the past, the Bogalusa Heart Study showed that 37% of its young adult participants (19-39 y) skipped breakfast (Nicklas et al., 1998). Several reasons for skipping of breakfast are suggested; for example, (1) low-income, and/or single-parent households with inadequate monetary resources to prepare or buy breakfast (Davy, Harrell, Stewart, & King, 2004; Miech et al., 2004); (2) time constraints (Sweeney & Horishita, 2005) for preparing and providing breakfast for their children; (3) unavailability of foods for breakfast (Malinauskas, Raedeke, Aeby, Smith, & Dallas, 2006); (4) poor health and nutrition knowledge among parents as well as children/adolescents (Sweeney & Horishita, 2005); and (5) weight concerns mainly among adolescent girls and/or young females (Malinauskas et al., 2006).

Despite the high prevalence rates for breakfast skipping in younger populations, very few studies have examined the effects of breakfast skipping on health parameters (e.g., overweight/obesity; metabolic syndrome [MetS], i.e., presence of ≥ 3 metabolic risk factors for cardiovascular disease [CVD] and/or type 2 diabetes mellitus [T2DM] (Grundy et al., 2006); and individual metabolic risk factors for CVD, T2DM, and the MetS). Presently, the US is facing an overweight/obesity epidemic. The prevalence of overweight (BMI $\geq 85^{th}$ percentile) and obesity (BMI $\geq 95^{th}$ percentile) in the US children/adolescents has almost tripled in the past three decades. In the time interval between NHANES II (1976-1980) and NHANES III (1988-1994), those children (6-11 y) having a BMI $\geq 95^{th}$ percentile increased from an estimated 7 % to 11%, and increased

from 5% to 11 % among 12-19 y adolescents (Centers for Disease Control and Prevention, 1999-2002). The current prevalence estimates (from the 2003-2004 NHANES) indicated that the percent of children/adolescents with a BMI ≥ 95th percentile was 18.8% in 6-11 y children and 17.4% in 12-19 y adolescents (Ogden et al., 2006).

Among the young adult population, the 2003-2004 NHANES prevalence estimates indicated that 57% were overweight (BMI ≥ 25) and 28.5% were obese (BMI ≥ 30) [Ogden et al., 2006]. These statistics depicted a marked increase from the NHANES III (1988-1991) statistical figures, with 24.1% of 20-29 y and 31.1% of 30-39 y young adults who were overweight and 13.6% of 20-29 y and 21.5% of 30-39 y young adults who were obese (Flegal, Kuczmarski, & Johnson, 1998). Concomitantly, the prevalence of MetS among young adults has also increased significantly from 13.3% (in the 1988-1994 NHANES) to 18.0% (in the 2003-2006 NHANES) (Ervin, 2009; Ford, Giles, & Mokdad, 2004).

With the rising prevalence of overweight/obesity and its related metabolic disorders, more research on the role of food consumption habits in relation to them are crucial. For example, breakfast being the first meal of the day may influence the intake of subsequent meals, energy intake, and metabolic profiles, and it is important to examine the role of breakfast skipping/consumption in relation to overweight/obesity and its related metabolic disorders. Further, not only skipping of breakfast should be considered a significant public health concern, but the type of breakfast consumed should also be

studied in relation to its nutritional and health benefits among breakfast consumers. The most commonly occurring category of breakfast is one that contains ready-to-eat breakfast cereal(s) (RTEC). Several RTEC available in the market are fortified with vitamins and minerals and are low in fat and/or high in dietary fiber (Anderson & Bridges, 1988; Ready-to-eat Cereals, 2008). Yet, a recent national survey reported that about 25% of Americans (>2 y) ate breakfast away from home and in doing so, consumed other breakfast foods (OB) that were high in total fat and cholesterol (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2001-2002). Concurrently, there is a paucity of recent US studies on the nutritional and health benefits of types of breakfasts consumed among younger populations (i.e., children/ adolescents and young adults). Hence, national US studies examining the role of type of breakfast consumption in conjunction with skipping patterns on the nutritional and health parameters in younger age groups are warranted.

Rationale(s)

Previous literature on the nutritional and health consequences of breakfast consumption habits has mainly concentrated on breakfast skippers (BS) in comparison with breakfast consumers (Nicklas et al., 1998; Nicklas et al., 2000). However, a recent analysis of US national surveys, regarding the role of different type of breakfasts consumed (i.e., RTEC vs. OB) on the nutritional and health parameters (e.g., adiposity status and metabolic risk factors) in younger age groups is lacking. In a previous NHANES III (1988-1994) analysis, conducted on adults (>18 y), Cho et al. (2003)

studied the association between different types of breakfast foods, as well as breakfast skipping, and BMI; their results showed that relative to the RTEC group (i.e., 17% of subjects), the skippers (i.e., 20% of subjects) had a significantly higher BMI, but a lower daily energy intake. However, these authors did not report data on intakes of individual macro- and micronutrients and the overall nutrient adequacy score (as indicated by the Mean Adequacy Ratio [MAR] for nutrients) with respect to breakfast consumption. Moreover, the relationship between nutrient intakes, BMI, and the prevalence of overweight/obesity among different types of breakfast consumers in children/adolescents was not examined. Thus, the first study in this dissertation proposed to investigate the relationship of breakfast skipping and type of breakfast consumed with intakes of energy, macro- and micronutrients, nutrient adequacy, and adiposity status in children/adolescents using the recent NHANES (1999-2006) data sets (Study I, Aims 1-2).

Young adulthood (> 19 y and < 40 y) is yet another critical period of transition from adolescence when individuals begin to live independently. Consequently, young adults may become susceptible to unhealthy dietary and lifestyle habits while trying to cope-up with pressures of responsibilities, independence, and balancing family and work life. The Bogalusa Heart Study has shown that young adults who skipped breakfast were less likely to meet two-thirds of the RDA for vitamins and minerals and they consumed lower amounts of protein and energy than breakfast consumers (Nicklas et al., 1998). Thus, the overall diet quality in those who skip breakfast may be compromised, or

lowered in individuals who do not consume healthy breakfast foods. However, to date, none of the studies has investigated the impact of both breakfast skipping and type of breakfast consumed on the overall diet quality (as evaluated by the current [2005] Healthy Eating Index [HEI] criteria), especially in the young adult age group. The 2005 Dietary Guidelines for Americans (DGA) endorse the HEI-2005 criteria set by the Center for Nutrition Policy for the assessment of diet quality (Guenther, Reedy, Krebs-Smith, Reeve, & Basiotis; United States Department of Agriculture's Healthy Eating Index, 2006). Furthermore, very few studies (Nicklas et al., 1998) have assessed energy, nutrient, and food consumption at the breakfast meal exclusively and none of the past studies has compared them among the different types of breakfast consumers in the young adults. Thus, the second study in this dissertation proposed to determine if breakfast skipping and differences in the types of breakfast consumed (i.e., RTEC vs. OB) would influence the intakes of energy, macro- and micronutrients, nutrient adequacy, and the intake of specific foods/food groups that are components of the HEI-2005 among young adults from the recent NHANES (1999-2002) data sets (Study II, Aims 3-6).

Despite the fact that young adults from the US face the problem of increased prevalence of overweight/obesity (Ogden et al., 2006) and MetS (Ervin, 2009; Ford et al., 2004), the effect of breakfast consumption habits on the prevalence of MetS and its related risk factors has not yet been investigated. Since: a) differences in breakfast consumption habits can influence the intakes of energy, macro- and micronutrients (for

example, increased intake of RTEC can increase the intake of several micronutrients [Affenito et al., 2005; Albertson et al., 2003; Song et al., 2006]); b) differences in micronutrient intakes resulting from differences in breakfast and/or overall food consumption (especially, calcium and dietary fiber intakes) are associated with differences in BMI (Van der Heijden, Hu, Rimm, & Van Dam, 2007; Zemel, Richard, Milstead, & Campbell, 2005); and c) increases in weight status/BMI is associated with deleterious effects on the qualifying criteria for MetS (Grundy et al., 2006; National Institutes of Health, 1998); the third study in this dissertation proposed to investigate the effects of breakfast skipping and type of breakfast consumed (i.e., RTEC vs. OB) on the occurrence of overweight/obesity, MetS, and its related individual metabolic risk factors in young adults using the recent NHANES (1999-2006) data sets (Study III, Aims 7-9).

Aims

The broad purpose of this dissertation was to explore the role of breakfast skipping and type of breakfast consumed in relation to nutrient and health parameters in younger age groups. The specific aims were accomplished via three separate studies using the current (1999-2006) NHANES datasets:

1. In children/adolescents (9-13 y/14-18 y), to examine differences in the intakes of energy, macro- and micronutrients, and nutrient adequacy (i.e., MAR for nutrients) among BS, RTEC, and OB consumers, after adjusting for covariates (i.e., age, energy intake, gender, ethnicity, ethnicity x gender, poverty income ratio, and physical activity) by using the 1999-2006 NHANES data sets (Study I).

2. In children/adolescents (9-13 y /14-18 y), to examine the differences in weight status measures (i.e., z-scores for BMI-for-age, waist circumference (WC), percent overweight, and percent obese) among BS, RTEC, and OB consumers, after adjusting for covariates (i.e., age, energy intake, gender, ethnicity, ethnicity x gender, poverty income ratio, and physical activity) by using the 1999-2006 NHANES data sets (Study I).
3. In young adults (20-39 y), to examine the differences in the intakes of energy, macro- and micronutrients among BS, RTEC, and OB consumers, after adjusting for covariates (i.e., age, energy intake, gender, ethnicity, ethnicity x gender, poverty income ratio, marital status, physical activity, smoking, and alcohol consumption) by using the 1999-2002 NHANES data sets (Study II).
4. In young adults (20-39 y), to examine differences in nutrient adequacy (i.e., MAR for nutrients) and diet quality (i.e., components of the HEI-2005 and the total HEI-2005 score) among BS, RTEC, and OB consumers, after adjusting for covariates (i.e., age, energy intake, gender, ethnicity, ethnicity x gender, poverty income ratio, marital status, physical activity, smoking, and alcohol consumption) by using the 1999-2002 NHANES data sets (Study II).
5. In young adults (20-39 y), to examine differences in intakes of energy, macro- and micronutrients, and food group consumption among breakfast consumers (RTEC and OB consumers) at the breakfast meal after adjusting for covariates (i.e., age, energy intake, gender, ethnicity, ethnicity x gender, poverty income ratio, marital status,

physical activity, smoking, and alcohol consumption) by using the 1999-2002 NHANES data sets (Study II).

6. In young adults (20-39 y), to determine percent consumption of different types of OB foods among RTEC and OB consumers by using the 1999-2002 NHANES data sets (Study II).
7. In young adults (20-39 y), to examine differences and/or associations in the occurrence of overweight/obesity among BS, RTEC, and OB consumers, after adjusting for covariates (i.e., age, energy intake, gender, ethnicity, ethnicity x gender, poverty income ratio, marital status, physical activity, smoking, and alcohol consumption) by using the 1999-2006 NHANES data sets (Study III).
8. In young adults (20-39 y), to examine differences and/or associations in the occurrence of individual metabolic risk factors for CVD, T2DM, and MetS (i.e., WC [for abdominal obesity], skinfold measurements, blood pressure, serum lipoproteins, plasma glucose and insulin, indices of insulin resistance and sensitivity, glycosylated hemoglobin, blood homocysteine, serum uric acid, and serum C-reactive protein) among BS, RTEC, and OB consumers, after adjusting for covariates (i.e., age, energy intake, gender, ethnicity, ethnicity x gender, poverty income ratio, marital status, physical activity, smoking, and alcohol consumption) by using the 1999-2006 NHANES data sets (Study III).
9. In young adults (20-39 y), to examine differences and/or associations in the overall occurrence of MetS among BS, RTEC, and OB consumers, after adjusting for

covariates (i.e., age, energy intake, gender, ethnicity, ethnicity x gender, poverty income ratio, marital status, physical activity, smoking, and alcohol consumption) by using the 1999-2006 NHANES data sets (Study III).

Null Hypotheses

1. In children/adolescents (9-13 y /14-18 y), there will be no differences in the covariate-adjusted intakes of energy, macro- and micronutrients, and nutrient adequacy scores among BS, RTEC, and OB consumers (Study I).
2. In children/adolescents (9-13 y /14-18 y), there will be no differences in the covariate-adjusted adiposity measures (i.e., BMI-z score-for age, WC, and occurrence of overweight/obesity) among BS, RTEC, and OB consumers (Study I).
3. In young adults (20-39 y), there will be no differences in the covariate-adjusted intakes of energy, macro- and micronutrients, nutrient adequacy scores, and diet quality scores among BS, RTEC, and OB consumers (Study II).
4. In young adults (20-39 y), there will be no differences and/or associations in the covariate-adjusted measures for adiposity (i.e., BMI, occurrence of overweight/obesity, body fat measures, and WC); the covariate-adjusted occurrence of individual metabolic risk factors for CVD, T2DM, and the MetS; and the covariate-adjusted overall occurrence of the MetS among BS, RTEC, and OB consumers (Study III).

CHAPTER II

REVIEW OF LITERATURE

The National Health and Nutrition Examination Survey (NHANES)

Overview

The NHANES program, which began in the early 1960s, has the responsibility for producing vital nutritional and health statistics for US children/adolescents and adults. The NHANES is conducted by the Centers for Disease Control and Prevention (CDC) and the National Center for Health Statistics (NCHS). The survey is unique in that it combines interviews and physical examinations. In 1999, the survey became a continuous program that had a changing focus on a variety of health and nutrition measurements to meet the emerging needs. The following versions of the NHANES are available: NHANES I (1971-1975); II (1976-1988); III (1988-1994); Hispanic HANES (1982-1984); NHANES I longitudinal study (1971-1992); and several continuous cross-sectional studies from 1999-2000, 2001-2002, 2003-2004, 2005-2006, and so on.

The findings from NHANES are used to determine risk factors for diseases (i.e., those aspects of a person's lifestyle, constitution, heredity, or environment) that may increase the chances of developing certain diseases or conditions. Further, data on smoking, tobacco, alcohol consumption, immunization records, sexual practices, drug use, physical fitness and activity, weight, dietary intake, and reproductive health (such as the use of oral contraceptives and breastfeeding practices) are also collected. The

NHANES thus helps to gather vital information on the prevalence and risk factors for various disorders such as overweight/obesity, diabetes mellitus, MetS, CVD and hypertension, cancer, osteoporosis etc. (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

Data Collection Procedures

Protocols, training, and study team. The NHANES program maintained high standards to ensure that non-sampling and measurement errors were minimized. Prior to data collection, extensive protocols were developed and reviewed by the public health and scientific community. Prior to and during data collection, the NHANES field staff participated in comprehensive training and annual refresher training for interviewers and the data collection staff. The NHANES interviews included demographic, acculturation, socioeconomic, dietary, lifestyle, and health-related questions conducted by highly trained interviewers. The examination component consisted of medical and physiological measurements, as well as laboratory tests administered by highly trained medical personnel, who followed rigid protocols. The study team of the NHANES consisted of a physician, medical and health technicians, as well as dietary and health interviewers (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

Recruitment. The NHANES was designed to examine nationally representative US sample of about 5,000 persons each year. Each participant in the survey represented approximately 50,000 other US residents. These persons were located in several counties

across the country, 15 of which were visited each year. The NHANES used adequate representation of all age groups, gender, ethnicities, and income. Certain individuals were over-sampled in the NHANES to ensure their adequate representation, which included African-Americans, Hispanics, individuals' ≥ 60 y, adolescents, and pregnant women (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

Participants from the NHANES were selected through a complex statistical process using the most current census information. In simple terms, NHANES divided the US into communities, which were further sub-divided into neighborhoods that were then selected at random. From each neighborhood, housing units were selected through another random sampling process. The identified households in the study area (from the above process of multistage probability sampling) received a letter from the NCHS director to introduce the survey. After administering an initial eligibility questionnaire to determine if their household was eligible for the study, the interviewer proceeded with efforts to recruit the individuals. Many of the study staff members were bilingual (English/Spanish) to facilitate the interview process (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

Institutional review board and consent forms. All NHANES procedures were reviewed and approved by the Institutional Review Board and Ethics Committee. All adults in the NHANES signed the consent form, children (>12 y) signed the consent form along with their parents, who also signed the consent form. Younger children (7-11 y)

signed an assent form and their parents signed the consent form; and for children (< 7 y), their parents signed the consent form (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

The NHANES was designed to facilitate and encourage maximum participation by the participants. The health interviews were conducted in the respondents' homes, whereas health measurements were performed in the specially designed and equipped mobile examination centers (MEC) that travelled to locations throughout the US. If necessary, transportation was provided to the participants to and from the MEC. All the participants received compensation and a report of their medical findings. Information collected in the survey was kept strictly confidential, and privacy of the participants was protected by public laws (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

Demographic data. All survey participants who had a household interview record also had a demographics file record. The household interview was conducted in-person with an interviewer in a language selected by the survey participants (English/ Spanish or any other language using a translator). Several questions required the use of printed hand cards (printed in either English/Spanish) that listed the response choices or provided information to the survey participants, and when necessary, the interviewers assisted the survey participants by reading the response choices listed on the hand card. For the demographics interview, a computer-assisted personal interview (CAPI) method was used. The demographics questions were designed to ascertain family-level and

individual-level information. Persons ≥16 y and emancipated minors were interviewed directly, while a proxy provided information on younger participants (<16 y). The interviewers were trained to assist and answer any queries that encountered the participants regarding the survey questions during the CAPI. Online help screens were also available to assist interviewers in defining key terms used in the questionnaire. The CAPI system was programmed with built-in consistency checks to reduce data entry errors (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

The following demographic variables recorded in the NHANES were used for the present dissertation. Age was recorded in years (between 1-84 y, and >85 y). Ethnicity was derived from responses to the survey questions on race and origin as reported by the subjects and included one of the following ethnicities (i.e., non-Hispanic white, non-Hispanic black, Hispanic, Mexican-American, and Other Race, that did not include any of the above ethnicities, or were multiracial). For all the three studies in this dissertation, Hispanic and Mexican-American ethnicities were combined together. Questions on marital status were asked to individuals' ≥14 y. If the marital status item was missing for persons (≥14 y), the information was imputed from other questionnaire items that referred to the respondent's marital status. Menstruating girls (8–11 y) and all girls/females (≥12 y) received a urine pregnancy test. Individuals who reported they were pregnant at the time of the examination were considered pregnant even if the urine test was negative. If the urine pregnancy results were negative and the respondent stated that

they were not pregnant, the respondent was coded 'not pregnant at examination'. Poverty income ratio, a surrogate measure of socioeconomic status was determined as the ratio of income to the family's appropriate poverty threshold. If a family's total income was less than that family's threshold income value (that was updated annually for inflation with the Consumer Price Index), then that family and every individual in it was considered poor. Masked Variance Units (MVU) were also included in the demographics data file that represented a collection of secondary or pseudo sampling units aggregated into groups. The MVU were created for the purpose of variance estimation that closely approximated the variances that would have been estimated if the 'true' sample design variance units based on the actual survey sample strata and primary sampling units were used. Thus, the MVU helped to protect confidentiality of information provided by the participants from the NHANES and reduced disclosure risks (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

Anthropometric data. All measurements in the NHANES were performed at the MEC. The body measurement component was conducted in a private room that was equipped with a floor scale, fixed stadiometer, a bench (for taking measurements in a seated position), wall mirror, and a computer workstation. The following measurements recorded in the NHANES were used in the present dissertation. Weight of the participants ($\geq$ 2 y) was measured by them standing on a floor scale that was equipped with a digital read-out. Stature (standing height) for participants ($\geq$ 2 y) was measured using a wall-mounted stadiometer. Waist circumference for participants ($\geq$ 2 y) was measured using a

steel measuring tape at the highest point of the iliac crest to indicate the mid-axillary line of the body. Sub-scapular skinfold measurements (obtained on the inferior angle of the right scapula) and triceps skinfold measurements (obtained on the midpoint of the posterior side of right upper arm circumference) for participants (≥ 2 months) were made using the Holtain skinfold calipers. All body weight data were captured electronically and entered into the survey database automatically (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006; Lohman, Roche, & Martorell, 1988).

Dietary data. Since 1999, the nutritional assessment component in the NHANES included a 24-hour dietary recall interview for participants of all ages conducted in person or by telephone (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006; Wright et al., 2007). All NHANES examinees were eligible for the dietary interview component. For all adults (≥18 y) and children (>12 y), data on dietary intake were obtained using the self-reported 24-hour dietary recall method. For children (6-11 y), parents/caregivers assisted them with dietary recalls; for children (1-5 y), parents gave proxy diet recalls. The dietary recall interviews were conducted in person by trained dietary interviewers fluent in English or Spanish in a private room in the MEC on either weekdays or weekends (Wright et al.). Depending on the type and number of foods reported in the dietary recall, the length of the interview ranged from 15-30 minutes per interview.

A computer-assisted dietary interview (CADI) software program with multi-stage probing was used to record detailed information about the reported consumption of foods/ beverages during the 24-hour dietary recall. The steps used in the CADI (see Figure 2) were as follows: At first, the respondent was asked to recall all foods/beverages consumed in a 24-hour period the day before the interview without interrupting. Then, the respondent was asked to report the time and place each food was eaten and what they would call the eating occasion for the food. Afterwards, a list of frequently forgotten foods was shown to probe the respondent for any forgotten foods/drinks. Then, specific food probes were used to collect detailed information for each food reported. This included a complete description of each food and the amount eaten. A set of measuring guides (including a United States Department of Agriculture [USDA] food model booklet, visuals including charts/drawings, a ruler, a set of household spoons, measuring cups/spoons etc.) were used to quantify the reported foods/beverages. Finally, the reported foods were reviewed with the respondent in chronological order. Any additional foods remembered during the process were added to the record as well as modifications for any reported foods were made. A status code was used by the dietary interviewers for the dietary interview component to indicate quality, reliability, and completeness of responses to the dietary recalls. The status code for the dietary recalls included the following criteria: < 25% of foods with missing descriptive information (e.g., preparation methods and brand names); < 15% of foods with missing amounts; and at least one known food in the reported meals (Centers for Disease Control and Prevention's National Health and

Nutrition Examination Survey, 1999-2006; Wright et al., 2007). The dietary data files were transmitted electronically to a coding center located offsite. A follow-up telephone dietary interview was also scheduled 3-10 days after the MEC exam for all the participants (the data from that follow-up dietary interview was not included in the present dissertation).

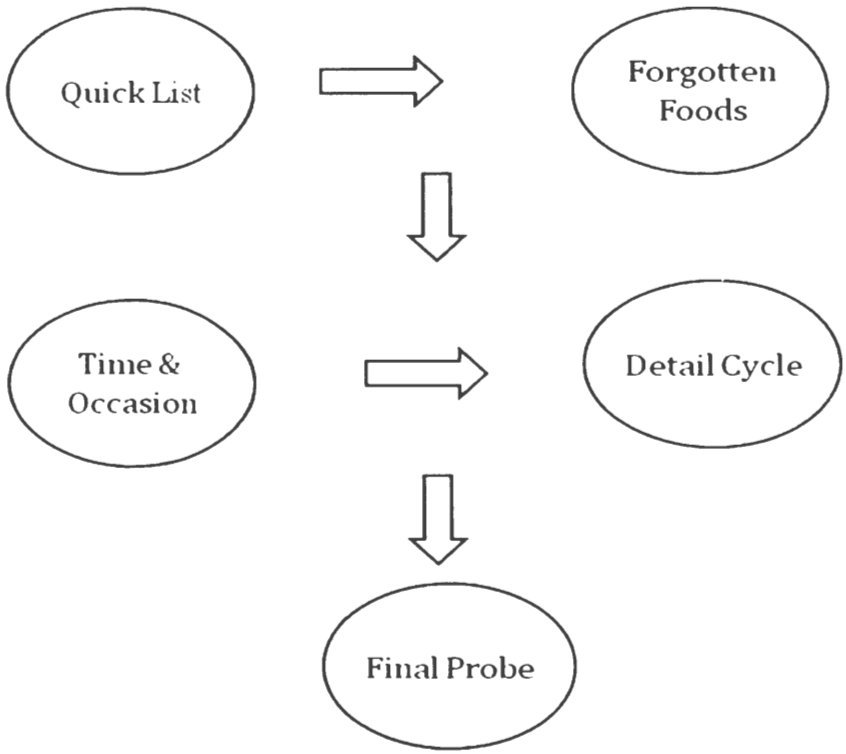

Figure 2. Five-step CADI: 24-hour dietary recall. *Note.* CADI = Computer Assisted Dietary Interview.

Despite the precision of the CADI, several limitations of using a single 24-hour dietary recall for purposes of dietary assessment ought to be considered. Self-reported dietary assessment techniques (including the multi-pass 24-hour dietary recall as used in the present dissertation) rely on the memory of participants, which may lead to reporting biases and reporting errors (Willett, 1998). Many times, individuals may under/over report consumption of foods and/or energy intake (Willett, 1998), either due to lack of knowledge or understanding or due to personal biases. Further, parents/guardians who assisted their children ≤ 12 y with the CADI in the NHANES may not have been aware of all the foods/beverages that the children may have consumed at the school or outside the home on the previous day. Lastly, 24-hour dietary recalls do not reflect the usual dietary intake patterns of the participants (Willett, 1998). Nevertheless, the interviewer-administered 24-hour dietary recall has long been regarded as the optimal methodology because it provides the highest quality and least biased dietary data for a single day and allows for the data collection on detailed intakes and portion sizes (Willett, 1998). Further, because the data collection occurs after consumption, this method does not affect an individual's food choices on a given day (Willett, 1998). In addition, data from disparate studies are relatively comparable using a 24-hour dietary recall because the query format is open-ended (Willett, 1998).

Lifestyle habits data. The smoking habits questionnaire was used to obtain smoking history data from all eligible survey participants (≥ 12 y). For adults (> 20 y), these questions were asked before the physical examination, at home, using the CAPI

system as discussed earlier. For the purpose of this dissertation, the following smoking questions were used: 'do you now smoke cigarettes' and 'have you smoked at least 100 cigarettes in your entire lifetime'; the final smoking status variable for studies two and three on young adults from the present dissertation was categorized into three lifetime smoking status groups: (1) 'never' (i.e., never smoked a cigarette or smoked fewer than 100 cigarettes in their lifetime); (2) 'past' (i.e., smoked at least 100 cigarettes in their lifetime, but did not currently smoke) ; and (3)'current' smokers (had 100 cigarettes in their lifetime and currently smoked everyday or on some days) (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). For this dissertation, the alcohol consumption data was obtained from the 24-hour dietary recall from the CADI system as discussed earlier. Physical activity for 9-11 y children was assessed by questionnaire data, which asked 'how many times per week does the child exercise enough to make them sweat and breathe hard?'. For children/adolescents 12-18 y, the physical activity interview asked 'if the child/adolescent participated in vigorous activities over the last 30 days?'; and another variable asked 'if the child/adolescent participated in moderate activities over the last 30 days'. For the purpose of study I (on children adolescents), the physical activity variable was categorized into three groups i.e., (1) 'vigorous' ($\geq$ 7 times per week), (2) 'moderate' (4-6 times per week), and (3) 'low' (0-3times per week) from the above-stated questions. For studies II and III (on young adults), the physical activity questionnaire for the adult age group was used to ascertain information on the 'average level of physical activity

each day' (i.e., whether the participants sit during day; stand/walk during the day; lift light loads or climb stairs or hills during the day; or lift heavy loads during the day); and the following variables were used to describe the physical activity patterns of the young adults : (1) 'sedentary', (2) 'light', (3) 'moderate', and (4) 'heavy' activity (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

Laboratory data. The laboratory component procedures in the NHANES included automated collection, processing, storage, and shipment of blood, urine, and other biological specimens to analytic laboratories. While the complete blood count and pregnancy analyses were performed in the MEC laboratory, most of the laboratory analyses were conducted off-site. A detailed explanation regarding specimen collection and processing instructions are described in the NHANES laboratory and medical technologists' procedures manual (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). The details of the laboratory techniques for study variables used in the present dissertation are described in study three, (chapter V).

The NHANES collected data on a few laboratory measures on subsamples of individuals (e.g., plasma glucose, serum triglycerides and low-density lipoprotein cholesterol [LDL-C]). For example, in 1999, the subsamples for the laboratory analyses comprised of one-fourth of participants aged 12–59 y; and in 2001-2002, the subsamples for plasma glucose and insulin comprised of one-half of the participants aged ≥ 12 y. In

addition, laboratory data on individuals who were fasting for at least 9 hours before blood draw were available for some measures in the NHANES (e.g., plasma glucose and insulin, and serum triglycerides and LDL-C). For the determination of blood pressure, the first and the fifth phase korotkoff readings (i.e., systolic and diastolic blood pressure) were recorded using a calibrated mercury sphygmomanometer, with three (and sometimes four) consecutive readings conducted by trained medical personnel (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

Quality control procedures. Quality control procedures in the NHANES were conducted for all types of data that were collected. The NHANES CAPI system (used for demographic/lifestyle information) had built-in edit and range checks for many question response options. When unusual or unrealistic responses were recorded, the interviewer was alerted immediately and instructed to verify or edit the initial response. During data preparation, variable frequency counts were checked, questionnaire 'skip' patterns were verified, and the reasonableness of responses to the questions were reviewed. The codebooks for each survey component included 'check item' variables, which were used internally at NCHS, as part of the quality control process to verify that the data collection processes was correct (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

The dietary interviewers in the NHANES were required to review and edit all of their interviews. Written guidelines for completing the required procedures were

developed for all survey staff. These procedures were reinforced during reviews of taped interviews and in-person observations, staff retraining, memos to the field, and informal e-mail correspondence. The initial quality control consisted of reviews of data transmittal sheets to verify receipt of data files; reviews of audiotaped interviews for approximately 5% of each interviewer's work; and reviews of completeness of the recalls. For example, dietary recalls were checked for missing information, inconsistent reports, and unclear notes, written notification, and feedback were provided to the interviewers. Also, about 10% of the dietary coders' work was double-coded and adjudicated if necessary to ensure quality and completeness. Further, staff retraining for interviewers and coders was conducted as needed and annual retraining sessions were held with all the MEC staff. To maintain quality control for anthropometric measurements, two individuals were needed, one being the trained examiner who would actually conduct the measurements and second being the recorder, who would record the values in the computer system. If a recorded value fell outside the pre-programmed edit range, the computer system would alert the recorder that the recorded value was unusual. The recorder always asked the examiner to verify the measurement value before proceeding to the next measurement. If a measurement or recording error were made, the recorder would enter the correct value; if the original value were correct, then the value would be retained (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

The laboratory team performance was also monitored using several techniques. The NCHS and contract consultants used structured quality assurance evaluations during unscheduled site visits to evaluate the quality of the laboratory work and implementation of the required quality control procedures. Laboratory staff were observed and given feedback with respect to equipment operation, specimen collection and preparation, interaction with survey participants, and implementation of the survey protocol. Formal staff retraining sessions were conducted annually to ensure that required skill levels were maintained. The quality control procedures for blood pressure assessment included the following elements: initial extensive training; quarterly re-certification by an expert consultant during field visits; a quality assurance plan including a procedural checklist; and continuous review of the data for systematic error (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006).

Data management and statistical analyses. An advanced computer system using high-end servers, desktop computers, and wide-area networking collected and processed all of the NHANES data. Interviewers at the MEC used notebook computers with electronic pens to automatically transmit the data into databases through the digital scales and stadiometers. Touch-sensitive computer screens let the respondents enter their own responses to certain sensitive questions in complete privacy. For data users and researchers throughout the world, survey data were made available on the internet and on compact discs. Since the NHANES used a complex probability sample, a proper analysis of the data usually required Statistical Analyses System (SAS) software and/or the

Statistical Software for Analysis of Correlated Data (SUDAAN) that specifically incorporated complications of stratified multistage probability sample design such as weighting and clustering (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). Sample weighting was done in the NHANES to account for the complex survey design (including oversampling), unequal probability of selection, survey non-response, and post-stratification issues. A weighted sample in the NHANES was thus representative of the US civilian non-institutionalized Census population. Further, for some laboratory measurements, sub-samples were used for conducting the analyses, which involved another stage of selection and separate sampling weights were needed to account for that stage of selection and additional non-response (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey).

Definition and Types of Breakfast

Breakfast in simple terms implies consumption of foods in the morning to 'break' the overnight fast and may consist of consumption of either solid foods, and/or beverages (Breakfast Research Institute, 2008). However, breakfast may have different meanings for different individuals. For example, individuals from some ethnicities (such as Mexican-Americans) consider 'brunch' (a combination of breakfast and lunch), as breakfast. Due to this, many breakfast studies (including the present dissertation) consider the definition of breakfast as 'self-reported' by the individuals instead of a single definition set by the researchers. The breakfast foods typically eaten by the general

US population (> 2 y) are breads/rolls, eggs, fruits, RTEC, along with beverages such as milk, coffee, fruit juices, and soda (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2001-2002). Ready-to-eat cereal also called breakfast cereal, is a cereal food that is processed to the point that it can be eaten without any additional preparation (Breakfast Cereals, 2009). Ready-to-eat cereal consumption at breakfast is regarded as a convenient, palatable and nutrient-dense, yet low-fat breakfast food choice that provides a good source of complex carbohydrates including dietary fiber. Most RTEC (up to 92% of those available) are fortified with several vitamins (especially, B vitamins such as vitamin B12 and folate) and minerals including calcium, iron, and zinc (Backstrand, 2002; Johnson, Smith, & Edmonds, 1998; Ready-to-eat Cereals, 2008; Subar, Krebs-Smith, Cook, & Kahle, 1998a; Subar, Krebs-Smith, Cook, & Kahle, 1998b; Whittaker, Tufaro, & Rader, 2001). For example, one serving (30 g) of 'Multigrain Cheerios' RTEC (before the addition of milk) provides 2.8 g dietary fiber; 14 mg α-tocopherol; 155 μg Retinol Activity Equivalent (RAE); 700 μg Dietary Folate Equivalent (DFE); 6.2 μg vitamin B12; 104 mg calcium; 83 mg phosphorus; 18.2 mg iron; 15.5 mg zinc; 88 mg potassium; and several other nutrients (Ready-to-eat Cereals, 2008).

Role of Breakfast Skipping and Consumption on Nutrient Intakes

Skipping of breakfast may have several adverse consequences, including reduced intake of many nutrients, which may not be compensated at other meals (Nicklas et al., 1998; 2000). Previously, children who skipped breakfast were more likely to be frequent

consumers of unhealthy snacks and were less likely to meet the recommendations for healthful foods such as vegetables and fruits (Utter, Scragg, Mhurchu, & Schaaf, 2007). On the other hand, children/adolescents who consume breakfast have better nutrient intakes than those who skip breakfast. Nicklas et al. (2000) found that the percent of adolescents from ninth-grade who consumed at least two-thirds of the daily RDA was higher for those who consumed breakfast than for those who skipped breakfast. Skipping breakfast could be one reason why children/adolescents have decreased intake of vitamins and minerals per 1,000 kcal as they grow older; and why many of the children/adolescents do not meet the RDA for vitamins A, E, and C, and folate; and minerals such as, calcium, potassium, and magnesium (Nicklas et al., 1998; 2000; 2004; United States Department of Agriculture, Dietary Guidelines for American's Shortfall Nutrients, 2005).

Breakfast and Macronutrient Intakes

The impact of eating breakfast on energy and macronutrient intake profiles has been examined in a few past studies, although the role of breakfast consumption on micronutrient intake status has been more extensively studied. In adults (>18 y) from the 1988-1994 NHANES, Cho et al. (2003), reported that the mean energy intakes of RTEC and cooked cereal consumers were higher than of those who skipped breakfast. Nicklas et al. (1998) reported that breakfast consumers in general had significantly higher mean energy and protein intakes than those who skipped breakfast in young adults from the Bogalusa Heart Study. Among children (4-12 y), Albertson et al. (2003) reported that

those in the upper tertile of RTEC consumption (i.e., ≥ 8 servings for two weeks consumed mainly at breakfast) had significantly lower mean fat and cholesterol intakes than those in the lower tertile of RTEC consumption (i.e., ≤ 3 servings for two weeks). Similar results were noted in the National Heart, Lung, and Blood Institute (NHLBI) Growth and Health Study, where Barton et al. (2005) found that after adjusting for energy intake, RTEC breakfast consuming American girls (9-10 y at baseline) had significantly lower mean intakes of fat and cholesterol compared to their non-RTEC breakfast consuming counterparts.

Breakfast and Micronutrient Intakes

The consumption of breakfast (especially the one than comprises of RTEC) has been associated with superior micronutrient intakes than skipping breakfast in several past studies (Albertson et al., 2003; Barton et al., 2005; Cotton, Subar, Friday, & Cook, 2004; Frary, Johnson, & Wang, 2004; Gibson, 2003; Kafatos et al., 2005; Song et al., 2006; Subar et al.,1998a; Subar, et al., 1998b; Van den Boom et al., 2006). Ready-to-eat cereal is mainly consumed at breakfast among most individuals, although a small percent of individuals may consume it at meals other than breakfast as well (Kafatos et al.; Nicklas, O'Neil, Myers, 2004). In the 1994-1996 Continuing Survey of Food Intake by Individuals (CSFII), Subar et al. (1998b) showed that consumption of RTEC was the top dietary contributor of several important vitamins and minerals in American children/adolescents (2-18 y). Frary et al. reported that the mean intake of folate in American children/adolescents (6–11 y and 12-17 y) met its RDA only in presweetened

RTEC consumers (>45 g/day) but did not meet the RDA in the non-consumers of RTEC. Albertson et al. reported that American children (4-12 y) in the upper tertile of RTEC consumption (i.e., ≥ 8 servings for two weeks consumed mainly at breakfast) had higher mean intakes of vitamins A and B6, thiamin, riboflavin, niacin, folate, calcium, iron, and zinc than those in the lowest tertile of RTEC consumption (i.e., ≤ 3 servings for two weeks). Further in the same study, the mean intakes of vitamin B6, thiamin, riboflavin, niacin, folate, calcium, iron, and zinc increased from the lower tertile of RTEC consumption to the upper tertile of RTEC consumption. Similarly, in the NHLBI study, Barton et al. reported that among American girls (9-19 y), days of eating breakfast were associated with higher mean intakes of dietary fiber and calcium and that after adjusting for energy intake, cereal consumption in particular was related to increased mean intakes of dietary fiber, vitamin C, folic acid, calcium, iron, and zinc compared to their non-RTEC breakfast consuming counterparts. Gibson (2003) reported that in children/adolescents (4-18 y) from Britain, the mean intakes of B vitamins, vitamin D, and iron were around 20-60% higher in those who were in the highest tertile of RTEC breakfast consumption compared to the lowest tertile (that included subjects who were non-consumers of RTEC and those who ate only 1-2 portions/week), with significant linear relationships observed for thiamin, riboflavin, folate, and iron (tertile 1 < tertile 2 < tertile 3). In Greek children/adolescents, Kafatos et al. reported that 60% of boys and 53% girls ($\bar{X}$=15 y) reported consuming RTEC at breakfast and that RTEC consumers had significantly higher mean intakes of dietary fiber, vitamins A and B6, riboflavin,

folate, calcium, magnesium, and iron than non-consumers of RTEC. In another study, on Spanish children/adolescents and young adults (2-24 y), Van den boom et al. found that the mean intakes of thiamin, riboflavin, and vitamin B6 increased significantly with increasing consumption of RTEC at breakfast in all age-gender groups, whereas the mean intakes of niacin and folate improved in almost all groups and calcium, iron, and vitamin D mean intakes improved in at least half of the groups. Also, in the same study, except for a few micronutrients (e.g., magnesium, vitamin B12, and vitamin E in males), consumption of RTEC was significantly associated with increased coverage of the daily nutrient requirements for all micronutrients studied.

Previously, higher levels of RTEC breakfast consumption (> 40 g) has also been associated with a higher consumption of dairy products in Spanish children/adolescents and young adults (2-24 y) (Van den Boom et al., 2006). Consumption of RTEC may help to augment the intake of calcium (Song et al., 2006), a mineral that is vital for bone accretion, in two ways: (1) by the typical addition of milk to RTEC (which provides >20% of the Daily Value per serving of calcium) and (2) due to the fortification of RTEC with calcium. For example, Song et al. reported that breakfast and milk consumption with or without RTEC, strongly predicted total daily calcium intake while controlling for covariates among all gender and age groups (≥ 4 y) participating in the 1999-2000 NHANES. In the same study, the percent of respondents below the Adequate Intake (AI) level for calcium (1300 mg/day in children/adolescents and 1000 mg/day in adults) was

higher for the non-RTEC breakfast consumers than for the RTEC breakfast consumers in all age-gender categories except those older than 70 y, and in girls, 9-13 y.

The most common underlying mechanism for the beneficial effects of RTEC consumption at breakfast is the fact that most RTEC are fortified with vitamins and minerals that may lead to an increased consumption of the same. Additionally, RTEC consumption may also increase the chances of consuming milk at the breakfast meal. Despite the above studies, recent national US studies comparing the nutritional impact of RTEC consumption at breakfast in comparison with non-RTEC breakfast foods, especially among younger age groups has not been adequately examined. More importantly, since people consume a variety of foods and nutrients, the intakes of which are often inter-correlated, it is important to assess the role of breakfast consumption in relation to nutrient/diet adequacy scores in conjunction with studying single nutrients. Yet, none of the past studies has examined the overall nutrient adequacy or diet quality scores with respect to breakfast consumption, especially among younger populations.

Role of Breakfast Skipping and Consumption on Health Parameters

Breakfast and Adiposity Status

Skipping of breakfast and/or not eating RTEC at breakfast has been associated with having a higher than normal BMI in children/adolescents (Affenito et al., 2005; Albertson et al., 2003; Barton et al., 2005; Timlin, Pereira, Story, & Neumark-Sztainer, 2008) as well as in adults (Cho et al., 2003; Mattes et al., 2002; Van der Heijden et al., 2007; Wyatt et al., 2002). Previously, Albertson et al. reported that American children

(4-12 y) who were in the upper tertile of RTEC consumption (i.e., ≥ 8 servings for two weeks consumed mainly at breakfast) had a lower mean BMI than those in the lowest tertile (i.e., ≤ 3 servings for two weeks) consistently across all age groups. Additionally, in the same study, the proportion of overweight children was significantly lower in the upper tertile of RTEC consumption than in the lower tertile. Barton et al. reported that days of eating RTEC was predictive of BMI *z* scores as well as risk of overweight in 9-10 y American girls; however, days of eating breakfast in general was not predictive of any BMI indicators in their study. Conversely, in a prospective analysis on American adolescents (15-19 y), frequency of breakfast consumption (daily, intermittent, and never) was inversely associated with BMI in a dose-response manner (Timlin et al., 2008). In another prospective analysis on American girls (9-10 y at baseline, and 19 y at follow-up) from the NHLBI study, Affenito et al. reported that after adjusting for demographic variables (i.e., age, ethnicity, and ethnicity x age), number of days of breakfast consumption was a significant predictor of BMI. These results were specifically observed in those girls who consumed cereals at breakfast on all three days and had 0.1 point lower BMI than those who ate cereals on 0, 1, or 2 days. However, after adding parental education, physical activity, and energy intake to the model, the above relationship was not significant.

Among adults (>18 y) from the 1988-1994 NHANES, Cho et al. (2003) reported that subjects who ate RTEC, cooked cereal, or quick breads for breakfast had significantly lower mean BMI compared to BS and to subjects who ate meat and eggs for

breakfast respectively. Additionally, the same study found that the mean BMIs of RTEC, cooked cereal, and the quick bread consumers were not significantly different from one another. In a prospective analysis, Van der Heijden et al. (2007) reported that among middle-aged and older US men (46 -81 y) breakfast consumption was inversely associated with the risk of 5-kg weight gain after adjustment for age, and this association was independent of lifestyle habits and their baseline BMI. The researchers of the above study reported that dietary fiber and nutrient intakes partially explained the association between breakfast consumption and weight gain. Further, in the same study, the inverse association between breakfast consumption and weight gain was more pronounced in men who were normal weight at baseline than in men who were overweight at baseline, and increasing the number of eating occasions in addition to three standard meals (that included breakfast) was associated with a higher risk of 5- kg weight gain. Song et al. (2005) using covariate-adjusted analyses (i.e., age, gender, ethnicity, smoking habits, and energy intake) in adults ($\geq$ 19 y) from the 1999-2000 NHANES, reported that among females, compared to breakfast non-consumers, those who consumed breakfast were 24% less likely to have a BMI $\geq$ 25. Further, the same research noted an inverse association between BMI and RTEC breakfast consumption in females but not in males.

Consumption of RTEC breakfast may also help in weight maintenance. Mattes (2002) found that RTEC when used as a breakfast food and as a portion-controlled meal replacement food for two weeks helped individuals (x= 43 y; $\bar{x}$ BMI = 28.9 kg/m^2) to lose more weight and fat mass, without changes in percent body water when compared to

the non-RTEC consuming groups in the study. Further, the weight loss continued even during the volumetric diet phase (comprising of healthy balanced, low energy-dense diet) during the seventh week of that study. Similarly, Wyatt et al. (2001) reported that in subjects ($\bar{X}$ age = 46.3 y) maintaining a weight loss in the National Weight Control Registry, 78% reported eating breakfast every day of the week, with 30% reported eating RTEC at breakfast every day.

Although the mechanisms linking breakfast consumption and lower body weight are unclear, several theories have been proposed. While those who eat breakfast tend to consume a higher total daily energy intake than those who skip breakfast (Nicklas et al., 1998; 2000), skippers tend to eat more foods with a low nutrient density (Nicklas et al., 2000), such as fast foods (Niemeier et al., 2006), and tend to consume a higher percent of energy from fat than breakfast consumers (Nicklas et al., 2000). Research also suggests that skipping breakfast may lead to an augmented appetite for energy-dense, but nutrient-poor meals (e.g., fast foods, [Niemeier et al., 2006] or unhealthy snacks [Utter et al., 2007]).

On the other hand, eating breakfast may be associated with an increased eating frequency, which may in turn promote more energy expenditure by increasing diet-induced thermogenesis, and may reduce hunger seen later in the day that may lead to overeating (Drummond, Crombie, & Kirk, 1996). The increased intake of calcium with the consumption of RTEC may also play a role in the regulation of body fat and body weight through the suppression of the lipogenesis promoting effects of calcitrol and

intracellular Ca^{2+} that occur as a result of a lower calcium intake (Zemel et al., 2005). Further, regular RTEC consumption at breakfast may also lead to more regular eating habits, may lead to a consistent energy intake, selection of more healthful food choices, and may boost exercise ability and sustainability (Kirwan, O'Gorman, & Evans, 1998), which may all contribute towards a lower BMI (Affenito et al., 2005; Utter et al., 2007). Despite these hypotheses, results from a longitudinal study by Berkey, Rockett, Gillman, Field, and Colditz (2003) noted that overweight children (9 -14 y) who skipped breakfast, had lower BMI values in the following year compared to overweight children who ate breakfast nearly every day; and normal weight children who skipped breakfast gained weight relative to peers who ate breakfast nearly every day. However, in the above study it was not known when the cereal (both hot/cold) was consumed, as some children who never ate breakfast consumed four bowls of cereal daily. Consequently, further investigation is required to confirm these findings.

Although the above literature review suggests the beneficial role of RTEC consumption at breakfast in lowering BMI, none of the studies to date has explored the comparison of consumption of RTEC vs. the consumption of OB foods with respect to BMI and other indices of adiposity such as the WC (as discussed later) and body fat measures.

Breakfast, Metabolic Syndrome (MetS), and Related Metabolic Risk Factors

To date only one study has examined the relationship between type of breakfast consumption and MetS. Devaraj, Wang-Polagruto, Polagruto, Keen, and Jialal (2008)

compared the postprandial effects of an energy-dense, high-fat, fast-food style breakfast meal with the American Heart Association recommended low-fat heart-healthy breakfast meal on biomarkers of oxidative stress and inflammation in subjects ($\bar{X}$ age = 49 ± 18 y, $\bar{X}$ BMI = 35 ± 5 kg/m^2) with MetS. Serum glucose levels were significantly higher two-hours after both breakfast meals; however, serum high-density lipoprotein cholesterol (HDL-C) levels decreased, while serum total triglyceride levels and interleukin-1b levels increased after the fast-food style breakfast meal, but not after the heart-healthy low-fat breakfast meal. Yet, the role of breakfast skipping and type of breakfast consumption on long-term metabolic effects (i.e., occurrence of MetS/related risk factors) among young adults remains to be elucidated.

Assessment of Nutrient Adequacy: The Mean Adequacy Ratio (MAR)

Given the complexity of human diets, the correlations among intakes of some nutrients with others, as well as several nutrient-nutrient interactions in function and metabolism that occur in the body, conclusion about the effects of intake of single nutrient on specific health outcomes may be misleading (Kant, 1996; Willett, 1998). Therefore, assessing indices of nutrient-adequacy based on nutrient scores rather than individual nutrient intakes per say may be beneficial (Kant, 1996). One such index is the MAR that easily permits an evaluation of the overall nutrient adequacy. For the calculation of MAR, first the nutrient adequacy ratio (NAR) defined as the ratio of a subject's nutrient intake to the current RDA for that nutrient for the subject's gender and age category, has to be calculated (Kant, 1996; Madden, Goodman, & Guthrie, 1976).

Additionally, the NARs are truncated at 100% of the RDA so that a nutrient with a high NAR may not compensate for a nutrient with a low NAR. When the truncated percents of the NAR are averaged, this allows for the estimates of the collective nutrient adequacy, enumerated as the MAR score for the nutrients examined (Kant, 1996; Madden et al.). Currently, there is no consensus for a best cut-point for nutritional adequacy for the MAR score. A previous validation study suggested the use of a conservative cut-point of ≥ 90 for the assessment of the total MAR score in children/adolescents and in adults (Krebs-Smith & Clark, 1989).

The MAR (and NAR) were initially developed to be used for nutrients having the RDAs. However, with the introduction of the four Dietary Reference Intake (DRI) guidelines (i.e., the RDA, the Estimated Average Requirement (EAR), the AI, and the Tolerable Upper Limit) (Institute of Medicine's Dietary Reference Intakes, 2006), either the EAR and/or RDA/AI may be used to calculate the MAR. Briefly, the RDA is an estimate of the daily average nutrient intake that meets the nutrient needs of nearly all healthy individuals in a particular age/gender group; while the EAR is defined as the nutrient requirements expected to satisfy the needs of 50% of the people in that age/gender group. The AI is used when no RDA and EAR for a nutrient has been established, but the recommendation for that nutrient is based on observed or experimentally determined approximations or estimates of nutrient intake by a group or groups of apparently healthy people that are assumed adequate for that particular demographic group. Examples of nutrients with AI values (instead of a RDA/EAR

value) are vitamins D and K, pantothenic acid, biotin, choline, calcium, potassium, sodium, chloride, chromium, fluoride, manganese, dietary fiber, linoleic acid, and alpha-linolenic acid. Finally, the Tolerable Upper Limit is defined as the recommendation used to caution against excessive intake of nutrients (e.g., vitamins A, and D) that can be harmful in large amounts.

Shortfall Nutrients

The MAR for shortfall nutrients was calculated in the same manner as described above for other nutrients. The 2005 DGA identified some nutrients as shortfall nutrients if a particular group had a high prevalence of inadequate dietary mean intakes (e.g., 60% below the EAR/AI) for those nutrients. These nutrients were thus considered as 'consumed in amounts low enough to be of concern' by the population (United States Department of Agriculture's Dietary Guidelines for Americans Shortfall Nutrients, 2005). For children/adolescents, five shortfall nutrients were identified, those being, vitamin E, calcium, magnesium, potassium, and dietary fiber. For adults, seven shortfall nutrients were identified, those being, vitamins A, E, and C, calcium, magnesium, potassium, and dietary fiber (United States Department of Agriculture's Dietary Guidelines for Americans Shortfall Nutrients).

Assessment of Diet Quality: The Healthy Eating Index (HEI)

The assessment of diet intake/quality in a population is important in policy making, in monitoring service outcomes, in designing epidemiological research, and evaluation of nutrition interventions (Guenther et al., 2007). In addition, the assessment

of dietary intake is an early indicator of potential health risks and complications especially among younger populations. Many factors may influence diet quality, including variability in the nutrient content of foods and in the daily intake of individuals (Kant, 1996; McCabe-Sellers et al., 2007). Despite the improved methods of nutrient assessment such as the establishment of the DRIs (as discussed earlier), translation of nutrient intakes into a comprehensive and meaningful dietary assessment remains a challenge, and therefore important gaps remain in the assessment of overall diet quality (McCabe-Sellers et al.).

The HEI is a measure of assessing the quality of a person's diet that assesses conformance to Federal dietary guidance. People eat foods and not nutrients; therefore, an index that addresses servings of foods that can be used by clinicians or consumers has its advantages (McCabe-Sellers et al., 2007). The HEI is used by the USDA to monitor changes in the nation's diet and can be used to assess diets of both individuals and groups. The HEI-2005 was developed to measure compliance with the key diet-related recommendations of the 2005 DGA, which had an increased emphasis on important aspects of diet quality, such as whole grains, various types of vegetables, specific types of fat, and the introduction of the new concept of discretionary calories (as discussed later). The food group standards in the HEI-2005 were based on the My-Pyramid recommendations (Britten et al., 2006; Guenther et al., 2007). The standards for the HEI-2005 were created using a density approach (i.e., they were expressed as a percent of calories or per 1,000 calories). The HEI-2005 was designed to assess the quality of the

relative proportions of foods consumed rather than the quantity of foods consumed. Further, new components for oils, and calories from solid fats, alcohol, and added sugars (SoFAAS), were introduced, and three subgroups of foods were added to the original HEI (i.e., whole fruits, dark green and orange vegetables and legumes, and whole grains). Like the 2005 DGA and My-Pyramid recommendations, the HEI-2005 recognized that some fats were more desirable than the others. Oils were recommended in the My-Pyramid; hence, they were also included in the HEI-2005 because they are excellent sources of essential fatty acids and vitamin E, which are in a short supply in the diets of Americans (Moshfegh, Goldman, & Cleveland, 2005).

The 12 food components from the HEI-2005 are shown in Table 1. For most components, higher intakes resulted in higher scores. However, for three components (i.e., saturated fatty acid [SFA], sodium, and calories from SoFAAS, lower intake levels resulted in higher scores because lower intakes were more desirable (Guenther et al., 2007; United States Department of Agriculture's Healthy Eating Index, 2006). In the HEI-2005, the food component scores were weighted equally, each receiving a maximum of 10 points with a few exceptions. Three food groups from the HEI-2005 had two components (i.e., total and a subgroup); for example, total fruits and whole fruits; total vegetables and dark green and orange vegetables and legumes; and total grains and whole grains; each of which got 5 points, so these three food groups (with their sub groups) effectively were allotted 10 points each (see Table 1). However, calories from SoFAAS were weighted twice as heavily as any other component and had a maximum score of 20

points (Guenther et al.; United States Department of Agriculture's Healthy Eating Index). This was mainly done to: (1) reflect the 2005-DGA that encouraged the selection of 'low-fat forms of foods in each food group as well as foods free of added sugars'; (2) because SoFAAS may displace nutrient-dense foods in the diet, and may add energy without adding nutrients; and (3) because SoFAAS are currently consumed in amounts that far exceed the discretionary calorie allowances (as discussed in detail later) (Basiotis, Guenther, Lino, & Britten, 2006). Intermediate scoring in the HEI was done proportionately. All HEI-2005 scores were evenly prorated, except for SFA and sodium, which were prorated from 0-8 and from 8-10 points (with 8 and 10 points representing acceptable and optimal levels, respectively, per the 2005 DGA recommendations).

For population monitoring, a single, summation score for the HEI-2005 may be calculated by using weighting of the HEI components to derive a total score, which can vary between 0 and 100. Nevertheless, rating of diet quality (such as good, fair, or poor) based solely on the total HEI-2005 score has not been recommended, since a 'fair' overall assessment could mean 'fair' on all components or 'outstanding' on some and 'poor' on others. Therefore, the individual food component HEI scores were designed to provide important and independent information about diet quality (Guenther et al., 2007; United States Department of Agriculture's Healthy Eating Index, 2006).

Table 1

The HEI -2005 Components and Standards for Scoring[1]

Components	Maximum points	Standard for maximum score	Standard for minimum score of zero
Total fruits (includes 100% juices)	5	≥ 0.8 cup equiv. /1,000 kcal	No fruits
Whole fruits (not juices)	5	≥ 0.4 cup equiv. /1,000 kcal	No whole fruits
Total vegetables	5	≥ 1.1 cup equiv. /1,000 kcal	No vegetables
Dark green/orange vegetables, and legumes[2]	5	> 0.4 cup equiv. /1,000 kcal	No dark green, orange vegetables, and legumes
Total grains	5	≥ 3.0 oz equiv. /1,000 kcal	No grains
Whole grains	5	≥ 1.5 oz equiv. /1,000 kcal	No whole grains
Milk[3]	10	≥ 1.3 cup equiv. /1,000 kcal	No milk
Meat/Beans	10	≥ 2.5 oz equiv. /1,000 kcal	No meat beans
Oils[4]	10	≥ 12 grams /1,000 kcal	No oil
SFA	10	≤ 7% of energy[5]	≥ 15% of energy
Sodium	10	≤ 0.7 gram /1,000 kcal[5]	≥ 2.0 grams per 1,000 kcal
Calories from SoFAAS	20	≤ 20% of energy	≥ 50% of energy

Note. HEI = Healthy Eating Index; equiv = equivalent; kcal = kilocalories; SFA = saturated fatty acids; SoFAAS = solid fat, alcohol, and added sugars. [1]Intakes between the minimum and maximum levels are scored proportionately, except for SFA and sodium (see note 5). [2]Legumes counted as vegetables only after meat/beans standard is met. [3]Include all milk products, such as fluid milk, yogurt, and cheese. [4]Include non-hydrogenated vegetable oils and oils in fish, nuts, and seeds. [5]SFA and sodium get a score of 8 for the intake levels that reflect the 2005 Dietary Guidelines,<10% of calories from SFA and 1.1 grams of sodium/1,000 kcal, respectively. From: United States Department of Agriculture. The Healthy Eating Index. (2006). Center For Nutrition Policy and Promotion. Fact Sheet No. 1.

Despite the new additions in the HEI-2005, several pitfalls in using this index have been pointed (Guenther et al., 2007). Although weight management, physical activity, and food safety, were included in the 2005 DGA, the HEI-2005 did not address them because the index was developed to be a measure of the nutritional quality of the diet *per se*. Further, the HEI-2005 does not apply to children < 2 y, and its validity for ethnic and cultural groups whose dietary patterns are markedly different from the American norm remains to be determined (Guenther et al.). Further, because the food patterns in My-Pyramid did not meet the RDA for vitamin E or the AI for potassium, a perfect score on the HEI may not ensure adequate intake of these nutrients to the same degree as it does for the other nutrients. In addition, lacking EAR-based standards, the HEI-2005 standards were set at the lowest level among the My-Pyramid recommendations for sedentary individuals. Also, the density standards did not capture the variability among age-gender groups in iron and calcium requirements (as reflected in the meat and beans and milk recommendations, respectively) nor in the discretionary calorie allowances. For example, the lowest discretionary calorie allowance was found in the 1,600-kcal My-Pyramid pattern and reflected the low-energy but high-nutrient needs of women. In contrast, the highest allowance, found at 3,200 kcal, reflected the high-energy needs and in comparison to their energy needs the relatively lower nutrient requirements of active teenage boys. Furthermore, the HEI-2005 does not directly capture excess consumption of the major food groups or oils. For example, since the mean intakes of refined grains and meat are above recommended levels for at least some

age-gender groups (United States Department of Agriculture's Dietary Guidelines for Americans, 2005), it can be concluded that they are contributing discretionary calories to some people's diets, however, the above concern is not addressed in the HEI-2005. In addition, the HEI-2005 does not address total fat, *trans* fats, or cholesterol directly, although they are mentioned in the 2005 DGA.

Despite the above-mentioned limitations, a psychometric evaluation of data from the 2001-2002 NHANES found that the HEI-2005 criteria were able to satisfy several types of validity tests, and reliability analyses. Moreover, the HEI-2005 criteria were successfully used to evaluate and compare the diet quality of Americans participating in the 1994-1996 CSFII and 2001-2002 NHANES (Guenther et al., 2007; United States Department of Agriculture, Center for Nutrition Policy and Promotion, 2007). The HEI-2005 is thus considered as a standardized tool that can be used in nutrition monitoring, interventions, consumer education, and research (Guenther et al.).

Added Sugars, Discretionary Fats, and Discretionary Calories

Added sugars are defined as sugars that are not naturally present in foods but are added during the processing or preparation of foods, including sugars and syrups added at the table. Added sugars are a part of the total sugars included in the diet. Names for added sugars in an ingredient list include brown sugar, corn sweetener, corn syrup, dextrose, fructose, fruit juice concentrates, glucose, high-fructose corn syrup, honey, invert sugar, lactose, maltose, malt syrup, molasses, raw sugar, sucrose, and syrup. Excess consumption of added sugars may contribute to the overconsumption

discretionary calories (United States Department of Agriculture's Dietary Guidelines for Americans, 2005). Therefore, the Institute of Medicine recommends that added sugars should not exceed > 25% of the total energy intake (Institute of Medicine's Dietary Reference Intakes, 2006). Between 1994 and 2002, Americans' intake of added sugars remained high and unchanged among 6- 19 y children/adolescents and increased among those ≥ 20 y. Data from the 2001-2002 NHANES indicated that the average percent of discretionary calories from added sugars by different age/gender groups in the US was much higher than recommended amount (< 25%), ranging between 30% and 42% of the total energy intake (Johnson et al., 2009).

Discretionary fats are defined as fats in a food above the amount that would be found in a lean, low-fat or fat-free form of the food, and include both solid and liquid fats. Solid fats are those fats that are solid at room temperature such as butter, shortening, and hydrogenated products and they contribute to discretionary calories. Most solid fats are also high in SFA and/or *trans* fats and have less monounsaturated fatty acids (MUFA) or polyunsaturated fatty acids (PUFA). Animal products containing solid fats also contain cholesterol. Liquid fats or (discretionary oils) (i.e., those from nuts/seeds, fish, and vegetable cooking oils) are liquid at room temperature, and are considered to contribute to discretionary calories only if they exceed the food intake pattern recommendation for oil consumption. Most liquid fats are high in MUFA or PUFA, and low in SFA except, coconut oil and palm kernel oil, which are both high in SFA, and are considered as solid fats (United States Department of Agriculture's Dietary Guidelines for Americans, 2005).

The concept of discretionary calories was introduced during the development of the 2005-DGA, to help people meet all of their nutrient requirements while avoiding excess total energy intake, through the consumption of foods low in fat or added sugars. A person's discretionary calorie allowance can be determined by estimating the energy needed (by age/gender group) to meet nutrient requirements and then subtracting this amount from the estimated energy requirement needed to maintain the body weight. The remaining calories are designated as the discretionary calorie allowance. The discretionary calorie allowance is thus part of total estimated energy needs, but not an addition to the total energy needs. Intakes of added sugars, solid fats, and alcohol are included within the allowance for discretionary calories, which proportionally increases as the total energy allowance increases. Thus, the discretionary calorie allowance may be used for forms of foods that are not the most nutrient-dense (e.g., whole milk rather than fat-free milk), for additions to foods (e.g., salad dressings, sugar, and butter), for alcoholic beverages, or for intake from any food group or oils over the amounts recommended.

Most discretionary calorie allowances are very small, between 100 and 300 kcal, especially for those who are not physically active. For example, an 1800 kcal pattern for a moderately active 51-55 y woman would have a 195 kcal discretionary allowance; whereas the allowance would be 512 kcal for a physically active 21- 25 y male, whose total energy allotment was 3000 kcal. These calculations provide consumers with an energy intake recommendation for weight maintenance based on their gender, height,

current weight, and physical activity level. If a lower energy intake is needed to achieve a healthy weight (which is the case for the majority of Americans, since about two-thirds of whom are overweight/obese [Ogden et al., 2006]), then the suggested amount of discretionary calories will be lower. One can increase the discretionary calorie allowance by choosing more nutrient-dense foods (i.e., those foods high in nutrients and low in energy [e.g., fruits and vegetables]); and by being physically active and/or exercising regularly.

Assessment of Adiposity Status

Overweight/obesity is most commonly defined using the BMI cut-offs. Among children/adolescents (2-20 y), those with BMI $\geq$ 85th percentile are classified as overweight, and those with a BMI $\geq 95^{th}$ percentile are classified as obese (Centers for Disease Control and Prevention, 2000). Among adults (> 20 y), a BMI value of $\geq$ 25 is considered overweight, and a BMI value of $\geq$ 30 is considered obese (Centers for Disease Control and Prevention; National Institute of Health, 1998). The prevalence of overweight/obesity using the BMI cut-offs has shown a continued epidemic increase in the US among all age groups (Ogden et al., 2006). Data from the 2003-2004 NHANES showed that the percent of children/adolescents with a BMI $\geq$ 85th percentile was 37.2% in 6-11 y children, and 34.3% in 12-19 y adolescents (Ogden et al.). Similarly, the percent of children/adolescents with a BMI $\geq$ 95th percentile was 18.8% in 6-11y children, and 17.4% in 12-19 y adolescents (Ogden et al.). In the same survey, among the young adults (20-39 y), 57% were noted to be overweight, 29% were noted to be

obese, and 5% were in the extremely obese category (BMI ≥ 40) (Ogden et al.). Serious co-morbidities associated with overweight/obesity are MetS, T2DM, CVD, hypertension, obstructive sleep apnea, non-alcoholic liver disease, and kidney disease (Ferris et al., 2007; Grundy et al., 2006; Reilly, 2005). Moreover, overweight in childhood tracks into young adulthood (Deshmukh-Taskar et al., 2006), which can exacerbate the risk for several overweight/obesity related chronic diseases (National Institute of Health, 1998). These grave consequences of overweight/obesity have contributed in escalating the nation's obesity attributed medical expenditures to 75 billion dollars in the year 2003 (Finkelstein, Fiebelkorn, & Wang, 2004).

Assessment of body fat (i.e., by triceps and sub scapular skinfold measurements) using a skin fold calipers is an old method for determining body fat in individuals. Although this method is very commonly used in research, a serious drawback of this measurement is the inaccuracy in the measurement techniques. Earlier, it was seen that fat mass estimated by dual-energy X-ray absorptiometry was significantly lower than the fat mass measured by skinfold thickness in children (Goran, Driscoll, Johnson, Nagy, & Hunter, 1996). Yet, measuring body fat using dual-energy X-ray absorptiometry is cumbersome and not feasible in many research studies. On the other hand, abdominal obesity (i.e., accumulation of both central subcutaneous and visceral fat) has recently emerged as an important predictor of metabolic complications and adverse health effects. Although subcutaneous/visceral fat can be accurately assessed by imaging techniques such as computerized tomography, and magnetic resonance imaging, using these

techniques to identify individuals in mass screenings or clinical settings may not be feasible. Waist circumference, a simple and convenient way of measuring abdominal or central obesity is considered a surrogate measure of abdominal obesity in children/adolescents (Li, Ford, Mokdad, & Cook, 2006) as well as in adults (Li, Ford, McGuire, & Mokdad, 2007). Studies have shown that WC may help to predict the risk of CVD in children/adolescents and in adults (Savva et al., 2000; Zhu et al., 2005). Further, compared to BMI, WC has been noted to be a better predictor of T2DM (Wang, Rimm, Stampfer, Willett, & Hu, 2005), MetS (Han et al., 2002), medical care costs (Cornier, Tate, Grunwald, & Bessesen, 2002), and all-cause mortality (Bigaard et al., 2005). Waist circumference is thus a major determinant of the National Cholesterol Education Program, Adult Treatment Panel III (NCEP ATP III) (Grundy et al., 2006) criteria for the definition and diagnosis of MetS. The National Institute of Health (NIH) recommends that WC be measured regularly, especially in people with a BMI of 25.0- 34.9 kg/m^2 (National Institute of Health, 1998).

Assessment of the Metabolic Syndrome (MetS)

Overview

Reaven (1988) coined a term called 'Syndrome X' that comprised of a cluster of metabolic aberrations in humans such as impaired glucose tolerance, hypertension, hypertriglyceridemia, and hypercholesterolemia (i.e., increased very low-density lipoprotein cholesterol [VLDL-C], decreased HDL-C); this author also postulated that insulin resistance was the primary cause of these metabolic aberrations, although he did

not include overweight/obesity in his original description. Subsequently, several other metabolic abnormalities have been known to be associated with this syndrome, including overweight/obesity, increased WC, microalbuminuria, and abnormalities in fibrinolysis and coagulation. The term MetS was later conceived by several other researchers denoting a constellation of risk factors of metabolic origin (such as obesity, T2DM and in many cases, hypertension, hypertriglyceridemia, and low levels of HDL-C) that are accompanied by increased risk of CVD and T2DM (Grundy et al., 2006).

The occurrence of MetS has been noted to be progressive, beginning with borderline risk factors that eventually progresses to severe/categorical risk factors (Grundy et al., 2006). Metabolic syndrome increases the risk for the occurrence of CVD by 2-fold and risk for the occurrence of T2DM by about 5-fold (Grundy, 2008) in adults compared to those without the syndrome, even with 'borderline-high' values for its risk factors. In addition, the constellation of risk factors for MetS confers a greater risk than is expected by the sum of its individual components (Cohn, Kittleson, & Blumenthal, 2005). In the future, MetS has been speculated to overtake smoking as the leading risk factor for heart disease (National Heart, Lung, and Blood Institute, 2007). Metabolic syndrome itself usually has no symptoms and most of the risk factors linked to MetS have no signs or symptoms, although a large waistline is a visible sign. Some people may have symptoms of high blood glucose (if diabetes is present) or, occasionally, hypertension. Symptoms of high blood glucose that may be present in individuals with MetS often include increased thirst, increased urination, especially at night, fatigue, and

blurred vision. In addition, in the early stages of hypertension, a few patients may have symptoms of dull headaches, dizzy spells, or nosebleeds. In premenopausal women with polycystic ovarian syndrome (an endocrine disorder, in which three principal features are overweight/obesity, lack of regular ovulation and/or menstruation, and excessive amounts or effects of androgenic hormones), the symptoms associated with MetS may be unexplained weight gain, infrequent menses and infertility, facial or body hair growth, as well as hair loss on the scalp (National Heart, Lung, and Blood Institute).

Prevalence

In the US, about 47 million adults (almost 25%) have MetS, and the numbers continue to grow (National Heart, Lung, and Blood Institute, 2007). The increasing number of people with this condition is connected to the rise in the prevalence of overweight/obesity rates among adults. More specifically, due to the current upsurge in the prevalence of overweight/obesity in young adults (Ogden et al., 2006), the occurrence of MetS has also increased among the young adult population (Ervin, 2009). Currently, in the US young adults, the prevalence of MetS has increased from 13.3% (in 1988-1994) to 18.0% (in 2003-2006) (Ervin, 2006).

Definitions

Several different definitions of MetS have been proposed earlier as depicted in Table 2. The World Health Organization (WHO), the European Group for the Study of Insulin Resistance (EGIR) and the International Diabetes Federation (IDF) criteria have an obligatory criterion in conjunction with some other risk factors for CVD T2DM:

whereas the NHLBI /American Heart Association (AHA) /Updated NCEP/ATPIII criteria (from the US) mandate the selection of a wider range of risk factors for identifying individuals with MetS, with no single mandatory criterion (see Table 2).

Currently, there are two most commonly followed definitions for MetS; 1) provided by the NCEP/ATPIII (from the US) and 2) provided by the IDF. The NCEP/ATPIII criteria (Grundy et al., 2006) categorizes individuals with MetS if ≥ 3 of the following five risk factors are present: (1) abdominal obesity (WC $\geq$ 102 cm in males and $\geq$ 88 cm in females); (2) elevated serum triglycerides ($\geq$150 mg/dL) or on drug treatment for decreasing serum triglycerides; (3) reduced serum HDL-cholesterol ($<$ 40 mg/dL in males or $<$ 50 mg/dL in females) or on drug treatment for increasing serum HDL; (4) elevated blood pressure ($\geq$ 130 or $\geq$ 85 mm Hg or those on drug treatment for elevated blood pressure /hypertension); and (5) elevated fasting plasma glucose ($\geq$ 100 mg/dl or those on drug treatment for elevated blood glucose [i.e., oral hypoglycemic agents/insulin]). The above NCEP/ATP III criteria include the most recently updated cut-point for elevated fasting plasma glucose which reduces the threshold for hyperglycemia from $\geq$ 110 mg/dL to $\geq$ 100 mg/dL, thereby bringing the ATPIII criteria for MetS in line with the American Diabetes Association's lowering of the levels of fasting glucose required to be considered impaired. Further, the inclusion of those subjects who use medications (for the treatment of elevated triglycerides, hypertension, hyperglycemia and reduced HDL-C), was also a new feature in the updated NCEP ATP III criteria (Grundy et al.).

On the other hand, the IDF criteria for MetS (see Table 2) place more emphasis on ethnicity-specific cut-offs for abdominal obesity (which is a mandatory criterion), and these cut-offs are lower than the cut-offs used in the NCEP/ATPIII criteria (Alberti, Zimmet, & Shaw, 2005; International Diabetes Federation, 2005). Hence, the IDF criteria help to generate greater prevalence estimates than the ATP III criteria, especially among the European population (Lorenzo et al., 2006). However, the use of abdominal obesity as a mandatory criterion for defining MetS by the IDF could result in the exclusion of subjects with ≥ 3 of the remaining four criteria, who might also have increased CVD prevalence (Assmann et al., 2007). The higher prevalence of overweight/obesity in the US and its concomitant metabolic risk factors appears to obliterate most of the differences in prevalence levels of MetS between IDF and the revised NCEP/ATP III criteria (Assmann et al.). Therefore, the revised NCEP/ATPIII criteria are more appropriate to classify individuals with MetS in the US.

Table 2

Definitions of MetS

Parameters	WHO (1998)	EGIR (1999, 2002)	ATP III/ AHA/ NHLBI (2001, updated 2004)	AACE (2003)	IDF (2004)
Obligatory criterion	T2DM/ IFG/ IR	Plasma insulin > 75th percentile	None	Clinical judgment based on risk factors	Central obesity (Criteria mentioned below)*
Other requirements	At least 2 of the following:	Any 2 of the following:	Any 3 of the following:	----------	At least 2 of the following:
Waist circumference	----------	> 94 cm (men) > 80 cm (women)	≥ 102 cm (men) ≥ 88 cm (women)	----------	Central obesity* ≥ 94 cm (Europoid men) ≥ 80 cm (Europoid women) Ethnicity-specific values for other ethnic groups
BMI kg/m2	> 30	---------	----------	≥ 25 kg/m^2	----------
Waist-to-hip ratio	> 0.9 (men) > 0.85 (women)	----------	----------	----------	----------

Table 2 continued

Parameters	WHO (1998)	EGIR (1999, 2002)	ATP III/ AHA/ NHLBI (2001, updated 2004)	AACE (2003)	IDF (2004)
Hypertension (mm Hg)	≥ 140/90	≥ 140/90 mm Hg/ on treatment	≥ 130 mm Hg / ≥ 85 mm Hg / drug treatment for hypertension	≥ 130/85 mm Hg	≥ 130 mm Hg / ≥ 85 mm Hg / specific treatment
Fasting blood/plasma glucose	≥ 110 mg/dl	IGT/IFG (not diabetes)	≥ 100 mg/dl/ drug therapy for IFG	110-126 mg/dL	≥ 100 mg/dl
2-hour Post-glucose challenge	----------	----------	----------	> 140 mg/dL	----------
Fasting serum triglycerides	≥ 150 mg/dl	≥ 150 mg/dl	≥ 150 mg/dl/ drug treatment for elevated triglycerides	≥ 150 mg/dL	≥ 150 mg/dl / specific treatment
Serum HDL-C	< 40 mg/dl (men) < 50 mg/dl (women)	< 39 mg/dl (men/women)	< 40 mg/dl (men) < 50 mg/dl (women) /drug treatment for low reduced HDL-C	----------	< 40 mg/dl (men) < 50 mg/dl (women)/ specific treatment

Table 2 continued

Parameters	WHO (1998)	EGIR (1999, 2002)	ATP III/ AHA/ NHLBI (2001, updated 2004)	AACE (2003)	IDF (2004)
Microalbuminuria	Yes	--------	--------	---------	--------
Other risk factors	---------	---------	--------	Family history of T2DM/ Hypertension/ CVD/PCOS sedentary lifestyle, advancing age, ethnic groups having high risk for T2DM/CVD	

Note. WHO World Health Organization; NCEP = National Cholesterol Education Program; ATP III = Adult Treatment Panel (III); NHLBI National Heart Lung and Blood Institute; AHA = American Heart Association; IDF = International Diabetes Federation; AACE = American Association of Clinical Endocrinologists; EGIR = European Group for the Study of Insulin Resistance; MetS = metabolic syndrome; T2DM = type 2 diabetes mellitus; IGT – impaired glucose tolerance; IFG = impaired fasting glucose; IR = insulin resistance; BMI = body mass index; HDL-C high-density lipoprotein cholesterol; CVD – cardiovascular disease; PCOS = polycystic ovarian syndrome. From: **A)** Banerjee, D., & Misra, A. (2007). Does using ethnic specific criteria improve the usefulness of the term metabolic syndrome? Controversies and suggestions. *International Journal of Obesity (London)* 3, 1340-1349. **B)** The International Diabetes Federation (IDF) (2005). A new worldwide definition of the metabolic syndrome consensus from the International Diabetes Federation could help stop the cardiovascular disease time bomb. Retrieved October 26, 2009, from *http://www.idf.org/webdata/docs/MetS_def_update2006.pdf.* **C)** Grundy, S.M., Cleeman, J.I., Daniels, S.R., Donato, K.A., Eckel, R.H., Franklin, B.A., et al. (2006). Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute scientific statement. *Current Opinion in Cardiology*, 21, 1-6.

Etiology

Metabolic syndrome seems to have three potential etiological categories: obesity and disorders of adipose tissue; insulin resistance; as well as a constellation of independent factors (i.e., molecules of hepatic, vascular, and immunologic origin) that mediate specific components of the MetS. Other factors (i.e., aging, pro-inflammatory state, and hormonal changes) have also been implicated as contributors as well.

Insulin and insulin resistance. Insulin is synthesized in the pancreas within the β-cells of the islets of Langerhans and is released when any of the several stimuli are detected, that include ingested protein and glucose in the blood produced from the digested food, stimuli from the autonomic nervous system, and exercise. Insulin signaling involves a cascade of events initiated by insulin binding to its cell surface receptor, followed by receptor autophosphorylation and activation of receptor tyrosine kinases, which results in the tyrosine phosphorylation of insulin receptor substrates (Kahn & Flier, 2000). Binding of the insulin receptor substrates to the regulatory subunit of phosphoinositide 3-kinase results in activation of phosphoinositide 3-kinase, which is necessary for insulin action on glucose transport. Downstream effectors (such as protein kinase B and protein Kinase C [PKC λ / ζ] isoforms) and GLUT 4 (a major insulin responsive glucose transporter) mediate insulin action on glucose transport (Kahn & Flier, 2000; Kim, Shulman, & Kahn, 2002).

The fundamental action of insulin is to control the plasma glucose concentration

by stimulating glucose transport into muscle and adipose tissue cells and inhibiting hepatic glucose output (Kahn & Flier, 2000). The physiological actions of insulin on cells thus include: (1) increased glycogenesis; (2) increased lipogenesis; (3) decreased lipolysis; (4) increased esterification of fatty acids; (5) decreased proteolysis; (6) decreased gluconeogenesis; (7) decreased autophagy of the β- cells; (8) increased amino acid uptake in the cells; (9) increased potassium uptake in the cells; and (10) maintaining arterial muscle tone (Insulin, 2009).

The most accepted hypothesis to describe the pathophysiology of the MetS is insulin resistance. Insulin resistance has traditionally been defined with a glucocentric view (i.e., a defect in insulin action results in fasting hyperinsulinemia in order to maintain euglycemia). Yet, even before fasting hyperinsulinemia develops, postprandial hyperinsulinemia exists (Eckel, Grundy, & Zimmet, 2005). A major contributor to the development of insulin resistance is an overabundance of circulating free fatty acids (FFAs) (Eckel et al., 2005). Plasma albumin-bound FFAs are derived mainly from adipose tissue triglyceride stores released through the action of the cyclic-adenosine-mono-phosphate dependent enzyme, the hormone sensitive lipoprotein lipase (LPL). Fatty acids are also derived through the lipolysis of triglyceride-rich lipoproteins in tissues by the action of LPL (Shaw, Hall, & Williams, 2005). Insulin is important to both antilipolysis and the stimulation of LPL (Kahn & Flier, 2000). Of note, the most sensitive pathway of insulin action is the inhibition of lipolysis in the adipose tissue. Thus, when insulin resistance develops, the increased amount of lipolysis of stored triglyceride

molecules in adipose tissue produces more fatty acids, which could further inhibit the antilipolytic effect of insulin, creating additional lipolysis. Upon reaching insulin sensitive tissues, excessive fatty acids create insulin resistance by the added substrate availability and by modifying downstream signaling.

In the muscle, fatty acids can impair activation of protein kinase C-λ and protein kinase C-ζ and can diminish protein kinase B activation, hindering the intracellular regulation of glycogen, glucose, and lipid metabolism (Kim et al., 2002). However, in the liver while circulating FFA increase hepatic glucose production and diminish inhibition of glucose production by insulin, lipogenesis, a pathway related to both the stimulatory effects of such acids and insulin on sterol response element binding protein-1c continues in an effort to maintain regulation (Eckel et al., 2005).

Obesity and increased waist circumference. The worldwide obesity epidemic has been the most important driving force in the much more recent recognition of MetS. Mechanistically, a distinction between a large waist due to increases in subcutaneous adipose tissue vs. visceral fat is debated. With increases in intra-abdominal/visceral adipose tissue, a higher rate of flux of adipose tissue-derived FFA to the liver through the splanchnic circulation would be expected, whereas increases in abdominal subcutaneous fat would release lipolysis products into the systemic circulation and avoid more direct effects on hepatic metabolism (i.e., glucose production, lipid synthesis, and secretion of prothrombotic proteins such as fibrinogen and plasminogen activator inhibitor 1). Despite these potential differences in mechanisms related to excessive abdominal adipose tissue

distribution, the clinical diagnosis of MetS does not distinguish between increases in subcutaneous and visceral fat (Eckel et al., 2005).

Dyslipidemia. In general, with increases in FFA flux to the liver, increased production of apolipoprotein B-containing triglyceride-rich VLDL occurs. In the setting of insulin resistance, increased flux of FFA to the liver increases hepatic triglyceride synthesis; however, under physiological conditions, insulin inhibits rather than increases the secretion of VLDL into the systemic circulation. This response in part is an effect of insulin on the degradation of apolipoprotein B. Yet, insulin is also lipogenic, increasing the transcription and enzyme activity of many genes that relate to triglyceride biosynthesis. The hormone sensitive LPL hydrolyses intracellular triglycerides in adipose tissue leading to sustained release of fatty acids into circulation and raised non-esterified fatty acid levels. Normally, the LPL is elevated under fasted conditions and reduced under fed conditions as result of inhibition by insulin. However, in insulin resistant subjects, hormone sensitive LPL activity is not fully suppressed in the fed state and non-esterified fatty acids levels are elevated. Thus insulin resistance could reduce the concentrations of LPL in peripheral tissues (i.e., in adipose tissue more than muscle) which may also contribute to hypertriglyceridemia (Shaw et al., 2005).

The other major lipoprotein disturbance in MetS is a reduction in HDL-C, a consequence of changes in HDL composition and metabolism. In the presence of hypertriglyceridemia, a decrease in the cholesterol content of HDL results from decreases in the cholesteryl ester content of the lipoprotein core with variable increases in

triglyceride making the particle small and dense, a function in part of cholesteryl ester transfer protein. This change in lipoprotein composition also results in an increased clearance of HDL from the circulation. The relation of these changes in HDL to insulin resistance is probably indirect, arising in concert with the changes in triglyceride-rich lipoprotein metabolism (Eckel et al., 2005).

The composition of LDL is also modified (in a similar way as described for HDL-C earlier) to form small-dense LDL. This change in LDL composition is attributable to relative depletion of unesterified cholesterol, esterified cholesterol, and phospholipid with either no change or an increase in LDL triglyceride. Small dense LDL might be more atherogenic than buoyant LDL (Lada & Rudel, 2004) because (1) it is more toxic to the endothelium; (2) it is more able to transit through the endothelial basement membrane; (3) it adheres well to glycosaminoglycans; (4) it has increased susceptibility to oxidation; and/or (5) it is more selectively bound to scavenger receptors on monocyte-derived macrophages (Lada & Rudel, 2004). In some studies, this alteration in LDL composition is an independent risk factor for CVD (Lada & Rudel, 2004). However, more often this association is not independent, but related to the concomitant changes in other lipoproteins and other risk factors (Eckel et al., 2005).

Glucose intolerance. The defects in insulin action in glucose metabolism include deficiencies in the ability of the hormone to suppress glucose production by the liver and kidney, and to mediate glucose uptake and metabolism in insulin sensitive tissues (i.e., muscle and adipose tissue). To compensate for defects in insulin action, insulin secretion

and/or clearance must be modified to sustain euglycemia. If this compensation fails, defects in insulin secretion predominate (Eckel et al., 2005). Insulin resistance in pancreatic islet β cells implies that signals that generate glucose-dependent insulin secretion have been adversely modified, and FFAs are the next prime candidates to stimulate insulin secretion. However, increasing and prolonged exposure to excessive concentrations of FFA results in falls in insulin secretion (Eckel et al.). The mechanism for this alteration has been attributed to lipotoxicity through several potential different unknown mechanisms (Yaney & Corkey, 2003).

Hypertension. The relation between insulin resistance and hypertension relates to several different mechanisms (Reaven, Lithell, & Landsberg, 1996). Insulin is a vasodilator, with secondary effects on sodium reabsorption in the kidney. In the setting of insulin resistance, the vasodilatory effect of insulin can be lost, but the renal effect on sodium reabsorption is preserved. Further, excess fatty acids themselves can mediate relative vasoconstriction. Insulin also increases the activity of the sympathetic nervous system, an effect that might also be preserved in the setting of the insulin resistance (Shaw et al., 2005).

Other manifestations. Insulin resistance is accompanied by many other alterations that are not included in the diagnostic criteria for the MetS (Eckel et al., 2005). Examples of metabolic alterations associated with insulin resistance include: (1) very low birth weight; (2) increases in CVD-promoting metabolic factors (e.g., apolipoproteins B and C-III, uric acid [elevated levels of which may block nitric oxide

availability that is essential for insulin to increase glucose uptake in the cells], prothrombotic factors [fibrinogen and plasminogen activator inhibitor 1], proinflamatory cytokines [interleukin-6, C-reactive protein, tumor necrosis factor, and resistin], serum viscosity, asymmetric dimethylarginine, homocysteine, as well as white blood cell count); (3) the presence of microalbuminuria, non-alcoholic fatty liver disease and/or non-alcoholic steatohepatitis; (4) obstructive sleep apnea; (5) low levels testosterone in men; (6) low levels of adiponectin (an anti-inflammatory cytokine produced by the adipocytes that enhances insulin sensitivity and decreases the inflammatory process); (7) polycystic ovarian disease in women; and (8) stressful life events (Eckel et al.).

Other Metabolic Risk Factors

Glycosylated/glycated hemoglobin is a form of hemoglobin used primarily to identify the average plasma glucose concentration over prolonged periods. It is formed in a non-enzymatic pathway by hemoglobin's normal exposure to high plasma levels of glucose. In the normal 120-day life span of the red blood cell, glucose molecules react with hemoglobin, forming glycosylated hemoglobin. Once a hemoglobin molecule is glycated, it remains that way. A buildup of glycosylated hemoglobin within the red cell therefore reflects the average level of glucose to which the cell has been exposed during its life cycle. The glycosylated hemoglobin level is proportional to average blood glucose concentration over the previous four weeks to three months. In general, the reference range (that is found in healthy persons), is about 4%–5.9%, and higher levels of glycosylated hemoglobin are found in people with persistently elevated blood glucose, as

in diabetes mellitus. The American Diabetes Association recommends that the glycosylated hemoglobin level be below 7.0% for most patients with diabetes, and <5.9% for normal individuals (Glycated hemoglobin, 2009).

Hyperhomocysteinemia is another risk factor for CVD and endothelial dysfunction (Hyperhomocysteinemia, 2009). Homocysteine is a non-dietary angiotoxic amino acid produced as a result of demethylation of methionine and can be recycled to methionine or converted to cysteine via multi-stage reactions. The conversion of 5,10-methylenetetrahydrofolate to tetrahydrofolate (the active form of folate in the body) provides the methyl group required to convert homocysteine to methionine (Shils, Shike, Ross, Caballero, & Cousins, 2005). Vitamins B6 and B12 act as cofactors for these reactions. Thus, a deficiency of B vitamins (especially folate) may lead to hyperhomocysteinemia and endothelial dysfunction, both of which are considered powerful risk factors for CVD (Moens et al., 2008). Yet, results from a recent meta-analysis indicated that not all studies suggest a positive relationship between hyperhomocysteinemia and CVD (Khandanpour, Loke, Meyer, Jennings, & Armon, 2009).

CHAPTER III

THE RELATIONSHIP OF BREAKFAST SKIPPING AND TYPE OF BREAKFAST CONSUMPTION WITH ENERGY AND NUTRIENT INTAKE, AND WEIGHT STATUS IN CHILDREN AND ADOLESCENTS: NHANES 1999-2006

(STUDY I)

Introduction

Pediatric overweight is epidemic in the United States (US) (Ogden et al., 2006). Childhood overweight tracks into adulthood (Deshmukh-Taskar et al., 2006), increasing the risk for chronic diseases that occur commonly among overweight/obese adults (National Institutes of Health, 1998). Dietary habits may contribute to the incidence and severity of overweight/obesity in children/adolescents (Albertson et al., 2003; Niemeier et al., 2006). Skipping breakfast has been associated with higher adiposity measures in children/adolescents and is more prevalent than in the past among these age groups (Seiga-Riz et al., 1998; Song et al., 2006). Previous nationally representative studies showed that in 1965, 5% and 12% of children/adolescents 11-14 years of age (y) and 15-18 y, respectively, skipped breakfast (Seiga-Riz et al.). The 1999-2000 National Health and Nutrition Examination Survey (NHANES) showed that 20.5% of 9-13 y children and 36.1% of 14-18 y adolescents, respectively, skipped breakfast (Song et al.).

Breakfast skipping may have public health consequences for children/adolescents (Affenito et al., 2005; Albertson et al., 2003; Barton et al., 2005; Nicklas et al., 2000; Niemeier et al., 2006; Utter et al., 2007). Compared to breakfast consumers, those who skipped breakfast had reduced intakes of many nutrients, including vitamins A, E, C, B6, B12, folate, iron, calcium, phosphorus, magnesium, potassium, and dietary fiber that were rarely compensated for at other meals (Nicklas et al.). Breakfast skippers (BS) were also less likely to meet the daily recommendations for food groups such as vegetables and fruits (Utter et al.). Skipping breakfast has been associated with a higher body mass index (BMI) compared to those who consume breakfast (Affenito et al.; Barton et al.). Skipping breakfast in childhood or adolescence may persist into adulthood (Lake et al., 2006). One strategy to increase the prevalence of those consuming breakfast was the introduction of the School Breakfast Program, which provides 25% of the Recommended Dietary Allowance (RDA) for energy, protein, vitamin A, and C, calcium, and iron (United States Department of Agriculture's School Breakfast Program, 1969-2009). However, not all schools or all children/adolescents participate in this program (Food Research and Action Center, 2005).

Many ready-to-eat cereals (RTEC) are convenient, palatable, nutrient-dense foods that do not require further preparation or cooking. Most RTEC are low in fat, are good sources of complex carbohydrates, and are fortified with vitamins and minerals (Cotton et al., 2004; Frary et al., 2004; Ready-to-eat Cereals, 2008; Subar et al., 1998b; Whittaker et al., 2001). Higher consumption of RTEC at breakfast has been associated with better

dietary intakes (Albertson et al.; Barton et al.; Frary et al.; Gibson, 2003; Subar et al.) when compared to lower or no consumption. Consumption of RTEC has also been related to a lower BMI and to weight loss (Albertson et al.; Barton et al.; Mattes, 2002) when compared to non-consumers. Nonetheless, studies exploring the relationship of breakfast consumption to nutrient intake (Affenito et al.; Barton et al.), nutrient adequacy, and anthropometric measures (Affenito et al.; Barton et al.) in a recent nationally representative sample of US children/adolescents are limited. The goal of this study was to examine the relationship between breakfast skipping and type of breakfast consumed using nutrient intake, nutrient adequacy, and anthropometric measures in a nationally representative sample of US children/adolescents.

Subjects and Methods

Study Design and Population

This study involved analyses of cross-sectional data from US children 9-13 y (n = 4,320) and adolescents 14-18 y (n = 5,339) participating in the 1999-2006 NHANES (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). Pregnant or lactating subjects (n = 129) were excluded. Due to the nature of the analysis (i.e., a secondary data analysis), and the lack of personal identifiers, this study was reviewed and approved in the exempt category by the Institutional Review Boards of Texas Woman's University, Houston, TX and Baylor College of Medicine, Houston, TX.

Dietary Assessment

The dietary data collection procedures are described elsewhere (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006; Wright et al., 2007). Briefly, data from a single multi-pass 24-hour dietary recall were used (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey; Wright et al.). For years where two-day dietary recalls were available from NHANES (i.e., from 2003 onwards), only the first day of dietary recall data was used to standardize the sample. The 24-hour dietary recall was assisted by parent/caregivers for children 6-11 y and was self-reported for those over 11 y (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey). Only participants with complete and reliable dietary data, as determined by the National Center for Health Statistics staff, were included. Breakfast consumption was defined as self-reported and included consumption of any food/beverage at a meal occasion named by the respondent as breakfast or desayuno/almuerzo (Spanish). Subjects who consumed no foods/beverages, excluding water, at breakfast were categorized as BS. Ready-to-eat cereal breakfast consumers were defined as those who ate RTEC at a breakfast meal occasion (regardless of other foods/beverages consumed at that meal occasion); and other breakfast (OB) consumers were defined as those who consumed other foods/beverages at the breakfast meal.

Intakes of total energy, total and percent energy from macronutrients, and micronutrients were assessed. The nutrient contents of survey foods in NHANES 2003-

2004 were determined using the United States Department of Agriculture (USDA's) Nutrient Database for Standard Reference, Release 20 (SR-20) (United States Department of Agriculture's National Nutrient Database, R20) and the SR-Link file (the recipe database) of the Food and Nutrient Database for Dietary Studies, version 2.0 (FNDDS 2.0) (United States Department of Agriculture's Food and Nutrition Database for Dietary Studies, 2.0). The USDA FNDDS, version 1 (United States Department of Agriculture's Food and Nutrition Database for Dietary Studies, 1.0), was used for processing the dietary interview data for 2001-2002, and technical support files included an earlier version of the recipe database used in NHANES 1999-2000. The versions of the SR nutrient databases linked to the survey foods were the SR-18 (United States Department of Agriculture's National Nutrient Database, R18) in NHANES 2001-2002 and the SR-16.1 (United States Department of Agriculture's National Nutrient Database, R16-1) in NHANES 1999-2000. The data for some nutrients (i.e., vitamins A and E and folate in their current accepted nutrient forms) and total sugars were obtained from the USDA's dietary database for vitamin A and E (United States Department of Agriculture's Dietary Database for Vitamins A and E, 1999-2002) and the FNDDS 2.0 (United States Department of Agriculture's Food and Nutrition Database for Dietary Studies, 2.0), respectively. The intake of added sugars (i.e., sugars added to foods/beverages during processing or home preparation and not natural sugars) was obtained from the My-Pyramid Equivalents Database for USDA's Survey (Version 2.0) (Bowman, Friday, & Moshfegh, 2008).

A mean adequacy ratio (MAR) of micronutrient intake was calculated by estimating the percent of the adequacy value (either Recommended Dietary Allowance [RDA] or Adequate Intake [AI] cut-off) (Institute of Medicine's Dietary Reference Intakes, 2006) that met the RDA/AI cut-off. Those values greater than the cut-off were truncated at 100% to prevent an excess intake of one nutrient from compensating for inadequate intake of other nutrients. These values were averaged over 13 selected micronutrients (vitamins A, E, C, B6, and B12; thiamin, riboflavin, niacin, folate, phosphorus, magnesium, iron, and zinc). The MAR for five shortfall nutrients (i.e., vitamin E, calcium, magnesium, potassium, and dietary fiber) as outlined by the 2005 Dietary Guidelines for Americans (DGA) committee (United States Department of Agriculture's Dietary Guidelines for Americans Shortfall Nutrients, 2005) was also calculated the same way as described above. Although there is no definite score for the interpretation of the MAR, a conservative score of ≥ 90 was selected as nutritionally adequate (Krebs-Smith & Clark, 1989).

Assessment of Adiposity Status

Adiposity status was assessed by using anthropometric measurements (i.e., weight, height, and waist circumference [WC]) conducted by NHANES personnel in the Mobile Examination Center (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006; Lohman et al., 1988). Body mass index was calculated as weight (kilogram)/height (m^2). The z-scores and percentiles for BMI-for-age and weight-for-age were calculated using the Statistical Analysis Software

program for the Centers for Disease Control and Prevention Growth Charts (Centers for Disease Control and Prevention, 2007). For children/adolescents, overweight was defined as a BMI ≥ 85th percentile and < 95th percentile; obesity was defined as a BMI ≥ 95th percentile (Centers for Disease Control and Prevention, 2000).

Covariates

Total energy intake, demographics (age, gender, ethnicity, ethnicity x gender), socioeconomic status (i.e., poverty income ratio [PIR]), and physical activity were covariates in the analyses. Demographic, socioeconomic and physical activity information was obtained from their respective NHANES questionnaires (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). Ethnicity of children/adolescents was self-reported and categorized into non-Hispanic Whites, non-Hispanic Blacks, Mexican-Americans/Hispanics, and Other/Mixed races. The PIR of the households was categorized in groups ranging from < 1 (indicating households below the poverty threshold) to ≥ 5. Physical activity of the children/adolescents was categorized into: 1) 'vigorous' (≥ 7 times per week), 2) 'moderate' (4-6 times per week), and 3) 'low' (0-3 times per week).

Statistical Analyses

Details regarding statistical methods are accessible elsewhere (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). Briefly, sample-weighted data were analyzed using Statistical Software for Analysis of Correlated Data (SUDAAN, 9.0.1) (Statistical Software Package for the

Analysis of Correlated Data, 2008) to account for unequal probability of selection from over-sampling and for the stratified multistage probability sample design (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey). Sample-weighted percents ± standard errors (SE) were calculated for the demographic variables using cross-tabulations and were compared using chi-square tests. Mean macro- and micronutrient intakes, MAR, BMI z-scores, and WC were determined and are presented as least-square means ± least-square standard errors. The covariate-adjusted prevalence of overweight/obesity was determined by calculating the mean of a dichotomous variable giving the 'mean prevalence percents' and standard errors. Tests for comparisons of means for dietary and anthropometric variables among the breakfast consumption groups were performed after adjusting for covariates using Bonferroni's correction ($p<0.05/3 = p<0.0167$) to adjust the significance level for multiple comparisons. The significance for categorical variables was set at $p \leq 0.05$.

Results

Demographic Characteristics

Twenty percent of children were BS, 35.9% consumed RTEC, and 44.0% consumed OB. A lower percent of Mexican-American/Hispanic and non-Hispanic White children were BS (16.1% and 19.4%) than consumed RTEC (35.5% and 37.6%) or OB (48.4% and 43.1%), respectively. A lower percent of children from households with PIR > 5 were BS (15.4%) than consumed RTEC (30.4 %) or OB (54.2%), respectively (see Table 3).

Thirty-two percent of adolescents were BS, 25.3% consumed RTEC, and 43.2% consumed OB. Fewer non-Hispanic White adolescents skipped breakfast (28.3%) or consumed RTEC (28.6%) than consumed OB (43.1%). A lower percent of non-Hispanic Black adolescents consumed RTEC (19.8%) than skipped breakfast (40.0%) or consumed OB (40.2%). A higher percent of Mexican-American/Hispanic adolescents consumed OB (45.0%) than skipped breakfast (32.9%) or consumed RTEC (22.2%). A lower percent of adolescents from households with PIR < 1 consumed RTEC (19.7%) than skipped breakfast (40.2%) or consumed OB (40.1%) (see Table 3). A lower percent of adolescents from single-parent homes consumed RTEC (20.7%) than skipped breakfast (35.4%) or consumed OB (43.9%) (*data not shown*).

Covariate-adjusted Mean Energy and Nutrient Intakes/Day by Type of Breakfast Consumption

In children, total energy intake in the group of BS was lower than those consuming RTEC or OB. Percent energy from both carbohydrate and total sugars were higher in RTEC consumers than in OB consumers or BS. Percent energy from added sugars was higher in BS than in OB consumers. Dietary fiber intake was higher in RTEC consumers than in BS or OB consumers. Percent energy from total fat, monounsaturated fatty acids, and polyunsaturated fatty acids were all lower in RTEC consumers than the other two consumption groups (see Table 4).

In children, intakes of vitamins A, C, B6, and B12, thiamin, riboflavin, niacin, folate, calcium, phosphorus, magnesium, iron, zinc, and potassium were all higher in

RTEC consumers than in BS. Other breakfast consumers had lower intakes of vitamins A, B6, and B12, thiamin, riboflavin, niacin, folate, calcium, phosphorus, magnesium, iron, zinc, and potassium but had a higher intake of sodium than RTEC consumers. Other breakfast consumers had higher intakes of only riboflavin and phosphorus when compared to BS (see Table 4).

In adolescents, the total energy intake for BS was lower than in RTEC and OB consumers. Percent energy from total carbohydrate, total sugars, and dietary fiber intake were all higher in RTEC consumers than in BS and OB consumers. Percent energy from added sugars was higher in BS than in RTEC and OB consumers. Percent energy from saturated fatty acids was higher in OB consumers than in RTEC consumers, and was lower in RTEC consumers than in BS. Cholesterol intake was higher in OB consumers than in BS and RTEC consumers (see Table 4).

In adolescents, those consuming RTEC had higher intakes of vitamins A, C, B6, and B12, thiamin, riboflavin, niacin, folate, calcium, phosphorus, magnesium, iron, zinc, and potassium than BS. Other breakfast consumers had higher intakes of vitamin A, riboflavin, calcium, phosphorus, magnesium, and potassium than BS; whereas they had lower intakes of vitamins A, C, B6, and B12, thiamin, riboflavin, niacin, folate, calcium, phosphorus, magnesium, iron, zinc, and potassium than RTEC consumers. Other breakfast consumers had higher intake of sodium than RTEC consumers. Among OB consumers, the intakes of thiamin, niacin, vitamins B6, B12, and K, folate, iron, zinc, and sodium did not differ from the BS (see Table 4).

Covariate-adjusted Mean Adequacy Ratio (MAR) For Nutrients Consumed/Day by Type of Breakfast Consumption

In children, the MAR for 13 selected micronutrients was higher in RTEC consumers ($\bar{X}$ = 91.3) than in BS ($\bar{X}$ = 79.0) and OB consumers ($\bar{X}$ = 84.7), and OB consumers had a higher MAR than BS. Similar results were observed within the age and gender groups. The MAR for the five shortfall nutrients was also higher in RTEC consumers ($\bar{X}$ = 63.7) than in BS ($\bar{X}$ = 55.9), and OB consumers ($\bar{X}$ = 59.7), and OB consumers had a higher MAR than BS (see Figure 3).

In adolescents, the MAR for 13 selected micronutrients was higher in RTEC consumers ($\bar{X}$ = 85.4) than in BS ($\bar{X}$ = 70.7) and OB consumers ($\bar{X}$ = 76.0), for both genders. The MAR for five shortfall nutrients was also higher in RTEC consumers ($\bar{X}$ = 54.9) than in BS ($\bar{X}$ = 45.9) and OB consumers ($\bar{X}$ = 49.5). Other breakfast consumers had higher MAR for the 13 selected micronutrients and for the five shortfall nutrients than BS (see Figure 3).

Covariate-adjusted Mean Anthropometric Measures by Type of Breakfast Consumption

In children, BS had a higher BMI-z-score-for-age than in RTEC consumers; overall, OB consumers had a higher BMI- z-score-for-age than RTEC consumers (see Figure 4). Breakfast skippers had a higher WC ($\bar{X}$ = 79.2 cm) than RTEC consumers ($\bar{X}$ = 75.9 cm); overall, OB consumers had a higher WC ($\bar{X}$ = 77.5 cm) than RTEC consumers (see Figure 5). The prevalence of obesity (BMI $\geq 95^{th}$ percentile) was higher

in BS ($\bar{X}$ = 22.1%) than in RTEC consumers ($\bar{X}$ = 15.2%), especially in boys ($\bar{X}$ = 24.1% vs.14.3%) (see Figure 6).

In adolescents, the BMI-z-score-for-age was higher in BS than in RTEC and OB consumers and was higher in OB consumers than in RTEC consumers (see Figure 4). Breakfast skippers had a higher WC ($\bar{X}$ = 78.5 cm) than RTEC consumers ($\bar{X}$ = 75.0 cm) and in girls, BS had a higher WC than OB consumers ($\bar{X}$ = 77.2 cm vs. $\bar{X}$ = 75.0 cm). Boys consuming OB had a higher WC ($\bar{X}$ = 78.7 cm) than boys consuming RTEC ($\bar{X}$ = 76.3 cm) (see Figure 5). The prevalence of obesity was higher in BS ($\bar{X}$ = 20.7%) than in RTEC consumers ($\bar{X}$ = 13.2%) in boys and girls. The prevalence of obesity was also higher in OB ($\bar{X}$ = 18.4%) than in RTEC consumers ($\bar{X}$ = 13.2%) in boys and girls (see Figure 6).

Discussion

Breakfast has been regarded as the most important meal of the day, in part because of its nutritional benefits (Affenito et al., 2005; Albertson et al., 2003; Barton et al., 2005; Gibson, 2003; Nicklas et al., 2000; Song et al., 2006; Utter et al., 2007). In this study spanning from 1999 to 2006, the prevalence of skipping breakfast was higher in adolescents (especially girls), than in children confirming results from previous studies (Barton et al.; Malinauskas et al., 2006; Seiga-Riz et al., 1998; Song et al.; Sweeney & Horishita, 2005). The percent of those consuming RTEC was lower than those consuming OB in all children/adolescents from this study.

A higher percent of children/adolescents from low-income households appeared to skip breakfast than those with other household income characteristics. Young populations are vulnerable to poor eating habits (Kipke et al., 2007), especially if they belong to households with inadequate monetary resources to provide breakfast (Miech et al., 2006; Wolfe & Campbell, 1993) or if their parents have limited time to prepare breakfast. Skipping breakfast may also occur because of a limited knowledge about health and nutrition (Davy et al., 2004), lack of time to eat or prepare breakfast (Sweeney & Horishita, 2005), unavailability of foods for breakfast (Sweeney & Horishita, 2005), or weight concerns (Malinauskas et al., 2006; Sweeney & Horishita, 2005), mainly among adolescent girls (Malinauskas et al.). Ethnic differences in breakfast consumption revealed that a higher percent of Other/Mixed race and non-Hispanic Black children/adolescents appeared to be among BS. Conversely, the percent of BS appeared to be the lowest in Mexican-American/Hispanic children. In all ethnicities, RTEC consumption was low, but it appeared to be lower in children/adolescents from non-Hispanic Black and Other/Mixed races compared to non-Hispanic Whites. High poverty rates or low-income among minority groups in the US may affect their choices of healthy food consumption (Deshmukh-Taskar, Nicklas, Yang, & Berenson, 2007; Goodman et al., 2003; Trevino et al., 2008). A recent study showed that compared to Whites, Blacks had lower accessibility to supermarket stores that could hinder their access and availability of healthy foods (Morland & Filomena, 2007), including fortified RTEC.

The mean intake of dietary fiber/day in all three breakfast consumption groups was below the AI value (Institute of Medicine's Dietary Reference Intakes, 2006) for children (i.e., 31 and 26 g/day in boys and girls, respectively) and for adolescents (i.e., 38 and 26 g/day, in boys and girls, respectively). Nevertheless, RTEC consumers still had a higher mean dietary fiber intake/day than BS and OB consumers. The dietary fiber content of one serving of RTEC may vary from 1% to about 60% of the Daily Value. Further, RTEC consumption may also be a way to increase whole grains in the diet; since an overwhelming majority of American children/adolescents fail to consume the recommended amounts (United States Department of Agriculture's Dietary Guidelines for Americans Shortfall Nutrients, 2005).

The benefits of consuming RTEC have been debated since they may contribute to added sugars in the diet (Frary et al., 2004), which if consumed in high amounts (>25% of total energy intake [Institute of Medicine's Dietary Reference Intakes, 2006; United States Department of Agriculture's Dietary Guidelines for Americans, 2005]), may promote weight gain (Bray, Nielsen, & Popkin, 2004; Duffey & Popkin, 2008). The present study showed that the mean intake of added sugars day was higher in BS than OB consumers in children, and in adolescents, it was higher in BS than RTEC and OB consumers, suggesting that BS consumed more added sugars during other times of the day. Yet, the consumption of added sugars did not exceed the above-stated recommendations in any of the breakfast consumption groups.

The American Academy of Pediatrics recommends that children/adolescents the age of those in this study should not consume more than 25-35% energy from fat and >300 mg of cholesterol daily (Gidding et al., 2006). On average, all breakfast consumption groups in this study consumed ≥ 30% but <35% energy from total fat during the day. The mean percent energy from fat/day was lower in RTEC consumers than in OB consumers and BS in children/adolescents. The mean cholesterol intake in all three breakfast consumption groups was < 300 mg/day; however, the mean cholesterol intake/day in OB consumers was higher than in RTEC consumers and BS in children/adolescents. A previous NHANES analysis suggested that OB foods eaten by Americans over the age of 2 y outside the home did not include RTEC, but included whole eggs, bacon/sausages, breads/rolls/sweet rolls, and fried potatoes (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2001-2002). These foods may contribute to high intakes of fat, cholesterol, and added sugars in the diet. In a recent study, middle-school children who participated in the School Breakfast Program, had lower intakes of RTEC (although offered in more than 75% of the school menus), but had higher intakes of milk and 100% fruit juices as well as biscuits/croissants/corn bread than the non-school breakfast consumers (Condon, Crepinsek, & Fox, 2009). Similarly, the adolescent school breakfast participants had lower intakes of unsweetened RTEC and fresh fruits compared to their non-school breakfast consuming counterparts. Yet, there was no difference in the overall milk consumption between the two adolescent breakfast groups (Condon et al., 2009). In this

study, the mean RTEC consumption was lower in adolescents than in children, suggesting that as age increases, RTEC consumption also declines.

Eating a healthy breakfast may help to meet the recommendations for DGA's shortfall nutrients (i.e., those nutrients that are consumed in amounts low enough to be of concern by children/adolescents) as well as several other nutrient requirements (Albertson et al. 2003; Suitor & Gleason, 2002; United States Department of Agriculture's Dietary Guidelines for Americans Shortfall Nutrients, 2005). Albertson and coworkers reported that the proportions of children not meeting their Estimated Average Requirement for vitamin A, folate, and zinc were the highest among those in the lowest tertile of RTEC consumption. In the present study, RTEC consumers had higher mean intakes of almost all vitamins and minerals/day, including B-vitamins, shortfall minerals (i.e., calcium, magnesium, and potassium), and some antioxidants (e.g., vitamins A and C) than BS and OB consumers. The increased intake of calcium among RTEC consumers may be attributed to the increased intake of milk that occurs with RTEC consumption, as also reported earlier (Song et al., 2006) or to the fortification of the RTEC. In the present study, 97% of children/adolescents consuming RTEC at breakfast did so with milk *(data not shown)*. Other breakfast consumers failed to consume higher intakes of many nutrients than BS during the day, including dietary fiber, thiamin, niacin, vitamins A and C (in children only); vitamins E, B6 and B12, folate, calcium (in children only), iron, and zinc. Compared to OB consumers and BS, RTEC consumers had a higher mean MAR for the intake of selected micronutrients in children adolescents. Although the

mean MAR for shortfall nutrients fell below the selected cut-off in the present study (Krebs-Smith & Clark, 1989) among all breakfast consumption groups, it was still higher for RTEC consumers than OB consumers and BS in children/adolescents. These results underscore the nutritional benefits of RTEC consumption at breakfast. Nonetheless, these results must be interpreted with caution, since the contribution of breakfast by itself to the total daily intake of nutrients was not examined.

Although the prevalence of overweight was not significantly different among breakfast consumption groups in children/adolescents, significant differences were found for BMI z-scores, WC, and the prevalence of obesity (i.e., BMI $\geq 95^{th}$ percentile). Waist circumference is a surrogate measure of abdominal obesity and is considered an important contributor of metabolic complications in children/adolescents (Li et al., 2006). The mean WC was higher in BS compared to RTEC consumers in children/adolescents. The prevalence of obesity was higher in BS than RTEC consumers in children/adolescents, and was higher in OB than RTEC consumers, in adolescents.

The results from the present analysis of anthropometric measures for the three breakfast groups are in agreement with most previous studies (Affenito et al., 2005; Albertson et al., 2003; Barton et al., 2005; Timlin et al., 2008). However, one longitudinal study (Berkey et al., 2003) reported that overweight children (9-14 y) who never ate breakfast had a larger decrease in their BMI compared to overweight children who ate breakfast nearly every day; whereas normal weight children who never ate breakfast gained weight relative to peers who ate breakfast nearly every day. Although

mechanisms linking breakfast consumption and lower body weight are unclear, several possible explanations may exist. While children/adolescents who consumed breakfast tended to consume a higher intake of total energy and total sugars than the BS (Nicklas et al. 2000), as was also observed in the present study for RTEC consumers; BS may tend to eat more foods with low nutrient or higher energy density (Nicklas et al.), such as fast foods (Niemeier et al., 2006), or may consume increased numbers of discretionary calories at other meals during the day. Skipping breakfast may also lead to excess hunger or rebound overeating (Miech et al., 2006) and consumption of large portion sizes (Lioret, Volatier, Lafay, Touvier & Maire, 2009) at subsequent meals. Conversely, breakfast consumption may be associated with an increased frequency of eating meals, which may reduce the efficiency of utilization of metabolizable energy and promote diet-induced thermogenesis and energy expenditure (Drummond et al., 1996). Moreover, healthy breakfast choices, such as fortified RTEC, may contribute to a lower fat intake, higher overall nutrient-density including an increased intake of calcium (Song et al., 2006), which has been suggested to play a role in reducing body fat (Zemel et al., 2005). Lastly, RTEC breakfast consumption may lead to more regular eating habits, a consistent energy intake, and selection of more healthful food choices (Song et al.; Utter et al., 2007), which may all aid towards achieving or stabilizing a lower BMI.

Limitations

Due to the cross-sectional design of NHANES, causality between breakfast skipping or consumption, nutrient intakes, and weight status cannot be established

(Willett, 1998). A single 24-hour dietary recall (as used in this study) may not capture the usual breakfast habits of the sample. Nevertheless, a single 24-hour recall is considered a reliable method of dietary assessment for large population groups (Willett, 1998). Parents assisted with the 24-hour recalls of children 9-11 y; parents can often report accurately what children eat in the home, but may not know what their children eat outside the home, which could result in reporting errors. The intake of nutrients contributed by vitamin-mineral supplements was not considered. In addition, this study did not determine the nutrient intakes solely from breakfast and dietary differences between breakfast consumption groups could be due to their intakes at other meals. It is also possible that RTEC consumers may have consumed other breakfast foods along with RTEC, which may have positively affected their nutrient intakes.

Conclusions

Nutrition professionals need to reinforce the importance of not only eating breakfast, but also consumption of healthy breakfast choices, such as RTEC, by children/adolescents. More research is needed to examine the impact of type of breakfast consumption on nutrient intakes and adiposity status over time in a nationally representative longitudinal sample of children/adolescents and using multiple days of dietary assessment.

Table 3

Demographic Characteristics by Type of Breakfast Consumption in Children (9-13 y) and Adolescents (14-18 y): NHANES 1999-2006

Demographics	BS			RTEC consumers			OB consumers			Row p value		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Sample size (n) (9-13 y)	930	459	471	1,536	785	751	1,854	878	976	-	-	-
Sample size (n) (14-18 y)	1,805	904	901	1,233	707	526	2,301	1,146	1,155	-	-	-
Sample size % ± SE (9-13 y)	20.1 ± 0.9	20.6 ± 1.2	19.7 ± 1.2	35.9 ± 1.0	37.7 ± 1.0	34.0 ± 1.4	44.0 ± 1.1	41.8 ± 1.5	46.3 ± 1.5	*	*	*
Sample size % ± SE (14-18 y)	31.5 ± 0.9	30.3 ± 1.2	32.7 ± 1.3	25.3 ± 0.9	27.8 ± 0.9	22.8 ± 1.2	43.2 ± 1.0	41.9 ± 1.3	44.6 ± 1.4	*	*	*
Age Mean ± SE (9-13 y)	11.4 ± 0.1	11.3 ± 0.1	11.4 ± 0.1	10.9 ± 0.1	11.0 ± 0.1	10.9 ± 0.1	11.0 ± 0.04	11.0 ± 0.1	11.0 ± 0.1	-	-	-
Age Mean ± SE (14-18 y)	16.2 ± 0.1	16.2 ± 0.1	16.1 ± 0.1	15.8 ± 0.1	15.7 ± 0.1	15.8 ± 0.1	15.9 ± 0.0	15.9 ± 0.1	15.9 ± 0.1	-	-	-

Table 3 continued

Demographics	BS			RTEC consumers			OB consumers			Row p value		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Ethnicity % ± SE (9-13 y)												
Non-Hispanic Whites	19.4 ± 1.2	19.7 ± 1.8	18.9 ± 1.7	37.6 ± 1.5	40.5 ± 1.5	34.5 ± 2.1	43.1 ± 1.6	39.7 ± 2.2	46.6 ± 2.2	*	*	*
Non-Hispanic Blacks	25.7 ± 1.2	25.1 ± 1.7	26.3 ± 1.7	33.1 ± 1.3	34.7 ± 1.3	31.6 ± 1.8	41.2 ± 1.4	40.2 ± 1.9	42.2 ± 1.9	*	*	*
Mexican-Americans/ Hispanics	16.1 ± 1.2	16.5 ± 1.7	15.8 ± 1.8	35.5 ± 1.7	35.7 ± 1.7	35.2 ± 2.5	48.4 ± 1.8	47.8 ± 2.5	49.0 ± 2.6	*	*	*
Other Mixed Races	26.3 ± 5.0	29.5 ± 7.2	21.7 ± 6.2	26.2 ± 4.6	22.6 ± 4.6	31.6 ± 7.1	47.5 ± 5.3	48.0 ± 7.3	46.7 ± 7.4	*		
Column p value	*	*	*	*	*		*	*		-	-	-
Ethnicity % ± SE (14-18 y)												
Non-Hispanic Whites	28.3 ± 1.2	27.3 ± 1.7	29.3 ± 1.8	28.6 ± 1.2	30.3 ± 1.2	26.8 ± 1.7	43.1 ± 1.4	42.3 ± 1.9	43.9 ± 1.9	*	*	*
Non-Hispanic Blacks	40.0 ± 1.2	40.0 ± 1.7	39.9 ± 1.8	19.8 ± 1.0	22.7 ± 1.0	16.8 ± 1.3	40.2 ± 1.2	37.3 ± 1.6	43.3 ± 1.8	*	*	*
Mexican-Americans Hispanics	32.9 ± 1.6	30.3 ± 2.2	35.6 ± 2.4	22.2 ± 1.4	26.5 ± 1.4	17.6 ± 1.7	45.0 ± 1.7	43.3 ± 2.2	46.8 ± 2.5	*	*	*

Table 3 continued

Demographics	BS			RTEC consumers			OB consumers			Row p value		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Ethnicity % ± SE (14-18 y)												
Other/Mixed Races	41.1 ± 4.5	40.2 ± 6.3	41.8 ± 6.3	12.1 ± 2.6	15.0 ± 2.6	9.4 ± 3.4	46.8 ± 4.4	44.7 ± 6.3	48.7 ± 6.3	*	*	*
Column p value	*	*	*	*	*	*				-	-	-
Physical activity % ± SE (9-13 y)												
Sedentary	21.0 ± 2.5	24.2 ± 4.4	18.5 ± 2.9	36.9 ± 2.9	38.0 ± 2.9	36.1 ± 3.6	42.1 ± 2.9	37.8 ± 4.4	45.5 ± 3.7	*		*
Moderate	18.5 ± 1.8	18.9 ± 2.8	18.1 ± 2.3	33.8 ± 2.3	33.6 ± 2.3	34.0 ± 2.9	47.8 ± 2.4	47.6 ± 3.8	47.9 ± 3.0	*	*	*
Vigorous	20.5 ± 1.1	20.4 ± 1.4	20.6 ± 1.6	36.5 ± 21.3	38.5 ± 1.3	34.1 ± 1.8	43.0 ± 1.3	41.2 ± 1.8	45.3 ± 2.0	*	*	*
Column p value										-	-	-

Table 3 continued

Demographics	BS			RTEC consumers			OB consumers			Row p value		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Physical activity % ±SE (14-18 y)												
Sedentary	37.7 ± 2.6	45.1 ± 4.4	33.3 ± 3.0	16.5 ± 1.9	17.9 ± 1.9	15.7 ± 2.4	45.8 ± 2.7	37.0 ± 4.1	51.1 ± 3.4	*	*	*
Moderate	35.2 ± 2.5	32.8 ± 4.1	36.7 ± 3.1	23.9 ± 2.2	26.3 ± 2.2	22.5 ± 2.7	40.8 ± 2.5	40.9 ± 4.2	40.8 ± 3.1	*		*
Vigorous	30.1 ± 1.0	28.8 ± 1.3	31.7 ± 1.6	27.2 ± 1.0	29.0 ± 1.0	24.9 ± 1.5	42.7 ± 1.1	42.2 ± 1.5	43.4 ± 1.7	*	*	*
Column p value				*	*	*				-	-	-
Family's PIR % ± SE (9-13 y)												
· 1	23.5 ± 1.9	26.3 ± 3.0	20.6 ± 2.2	33.4 ± 1.9	30.3 ± 1.9	36.4 ± 2.7	43.2 ± 2.1	43.4 ± 3.1	43.0 ± 2.7	*	*	*
· 1 and · 2	24.1 ± 1.9	22.0 ± 2.5	26.0 ± 2.7	37.5 ± 2.2	40.9 ± 2.2	34.1 ± 2.9	38.5 ± 2.2	37.1 ± 3.2	39.9 ± 3.0	*	*	*
· 2 and · 3	17.8 ± 2.0	18.1 ± 2.8	17.6 ± 2.9	38.4 ± 2.6	41.6 ± 2.6	34.9 ± 3.7	43.8 ± 2.6	40.3 ± 3.6	47.6 ± 3.8	*	*	*
· 3 and 5	17.8 ± 1.8	17.7 ± 2.5	17.8 ± 2.6	38.2 ± 2.3	41.8 ± 2.3	34.1 ± 3.2	44.0 ± 2.3	40.5 ± 3.2	48.1 ± 3.4	*	*	*
5.0 +	15.4 ± 2.3	18.4 ± 3.5	12.2 ± 3.0	30.4 ± 3.0	30.3 ± 3.0	30.6 ± 4.2	54.2 ± 3.3	51.4 ± 4.7	57.2 ± 4.5	*	*	*

Table 3 continued

Demographics	BS			RTEC consumers			OB consumers			Row p value		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Family's PIR % ± SE (9-13 y)												
Column p Value	*		*		*		*		*	-	-	-
Family's PIR %± SE (14-18 y)												
< 1	40.2 ± 1.9	38.0 ± 2.7	42.3 ± 2.7	19.7 ± 1.5	22.0 ± 1.5	17.5 ± 2.0	40.1 ± 1.9	40.0 ± 2.7	40.2 ± 2.7	*	*	*
≥ 1 and < 2	32.5 ± 1.9	34.9 ± 2.8	29.9 ± 2.8	25.6 ± 1.9	26.6 ± 1.9	24.5 ± 2.8	41.9 ± 2.1	38.5 ± 2.8	45.6 ± 3.1	*	*	*
≥ 2 and < 3	30.9 ± 2.0	28.7 ± 3.0	33.2 ± 3.3	24.7 ± 2.1	27.5 ± 2.1	21.7 ± 2.9	44.4 ± 2.4	43.8 ± 3.4	45.1 ± 3.5	*	*	*
≥ 3 and < 5	29.0 ± 1.9	26.7 ± 2.5	31.4 ± 2.8	29.1 ± 1.9	33.3 ± 1.9	24.7 ± 2.6	42.0 ± 2.1	40.1 ± 2.9	44.0 ± 3.0	*	*	*
5.0 +	23.3 ± 2.2	22.4 ± 2.9	24.3 ± 3.2	28.6 ± 2.3	29.3 ± 2.3	27.8 ± 3.4	48.1 ± 2.6	48.3 ± 3.5	47.9 ± 3.8	*	*	*
Column p value	*		*	*	*	*				-	-	-

Note. NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; PIR = poverty income ratio; * = significant difference at $p<0.05$ from chi-square test. Values are sample-weighted percents ± standard errors or sample-weighted least-squared means ± least-squared standard errors. Mean percents across the three breakfast groups in rows (BS, RTEC consumers, and OB consumers) add to 100 and the significance is indicated by row p values (*$p<0.05$) for both genders, boys, and girls. Column percents (*data not shown*) are indicated with column p values (*$p<0.05$).

Table 4

Energy and Nutrient Intakes from a Reported 24-hour Dietary Recall by Type of Breakfast Consumption in Children (9-13 y) and Adolescents (14-18 y): NHANES 1999-2006

	9-13 y (n = 4,320)			14-18 y (n =5,339)		
	BS (n = 930)	RTEC consumers (n = 1,536)	OB consumers (n = 1,854)	BS (n = 1,805)	RTEC consumers (n = 1,233)	OB consumers (n = 2,301)
Nutrient parameters	LSM ± LSSE					
Energy (kcal)	2033.0 ± 54.2[a]	2266.0 ± 37.5[b]	2270.0 ± 36.0[b]	2032.0 ± 43.8[a]	2462.0 ± 47.5[b]	2352.0 ± 41.9[b]
Protein (g)	77.3 ± 1.2	78.2 ± 0.9	78.0 ± 0.9	73.8 ± 1.1[a]	77.9 ± 1.1[b]	77.4 ± 1.0[b]
Protein (% energy)	13.7 ± 0.2	13.9 ± 0.2	13.9 ± 0.2	13.3 ± 0.2	13.6 ± 0.2	13.7 ± 0.2
Total carbohydrate (g)	295.2 ± 2.6[a]	311.1 ± 2.2[b]	297.8 ± 2.2[a]	299.2 ± 2.6[a]	320.4 ± 2.4[b]	296.1 ± 2.3[a]
Carbohydrate (% energy)	52.6 ± 0.5[a]	55.6 ± 0.4[b]	53.0 ± 0.4[a]	53.1 ± 0.5[a]	56.4 ± 0.4[b]	52.6 ± 0.4[a]
Total sugars (g)	151.4 ± 3.5[a]	163.2 ± 2.6[b]	150.0 ± 2.5[a]	154.2 ± 3.3[a]	166.6 ± 3.0[b]	149.4 ± 2.7[a]
Total sugars (% energy)	26.8 ± 0.7[a]	29.1 ± 0.5[b]	26.6 ± 0.4[a]	27.7 ± 0.5[a]	29.1 ± 0.5[b]	26.5 ± 0.4[a]
Added sugars (g)	118.7 ± 3.2[a]	112.3 ± 2.6[a,b]	108.3 ± 2.5[b]	125.5 ± 3.1[a]	114.2 ± 2.9[b]	110.9 ± 2.6[b]
Added sugars (% energy)	21.2 ± 0.6[a]	20.0 ± 0.5[a,b]	19.0 ± 0.4[b]	22.5 ± 0.6[a]	20.0 ± 0.5[b]	19.1 ± 0.4[b]

Table 4 continued

	9-13 y (n = 4,320)			14-18 y (n =5,339)		
	BS (n = 930)	RTEC consumers (n = 1,536)	OB consumers (n = 1,854)	BS (n = 1,805)	RTEC consumers (n = 1,233)	OB consumers (n = 2,301)
Nutrient parameters	LSM ± LSSE					
Total fat (g)	85.6 ± 1.0[a]	78.7 ± 0.8[b]	84.1 ± 0.8[a]	85.2 ± 0.9[a]	77.3 ± 0.9[b]	86.4 ± 0.8[a]
Total fat (% energy)	33.6 ± 0.4[a]	30.5 ± 0.3[b]	33.2 ± 0.3[a]	33.6 ± 0.4[a]	30.0 ± 0.3[b]	33.7 ± 0.3[a]
SFA (g)	29.3 ± 0.4	28.6 ± 0.4	29.0 ± 0.4	29.4 ± 0.4[a,b]	28.2 ± 0.4[a]	29.9 ± 0.4[b]
SFA (% energy)	11.5 ± 0.2	11.1 ± 0.1	11.4 ± 0.1	11.6 ± 0.2[a]	10.9 ± 0.2[b]	11.7 ± 0.1[a]
MUFA (g)	32.3 ± 0.4[a]	28.7 ± 0.3[b]	31.8 ± 0.3[a]	32.7± 0.4[a]	28.6 ± 0.4[b]	33.0 ± 0.3[a]
MUFA (% energy)	12.7 ± 0.2[a]	11.1 ± 0.1[b]	12.5 ± 0.1[a]	12.9 ± 0.2[a]	11.1 ± 0.1[b]	12.8 ± 0.1[a]
PUFA (g)	17.3 ± 0.4[a]	15.0 ± 0.3[b]	16.5 ± 0.3[a]	16.7 ± 0.4[a]	14.2 ± 0.3[b]	16.7 ± 0.3[a]
PUFA (% energy)	6.8 ± 0.2[a]	5.8 ± 0.1[b]	6.5 ± 0.1[a]	6.6 ± 0.1[a]	5.5 ± 0.1[b]	6.5 ± 0.1[a]
Dietary fiber (g)	13.3 ± 0.3[a]	14.5 ± 0.3[b]	13.3 ± 0.2[a]	12.6 ± 0.3[a]	15.0 ± 0.3[b]	13.0 ± 0.2[a]
Cholesterol (mg)	233.9 ± 7.8[a]	218.3 ± 6.2[a]	284.2 ± 8.0[b]	210.9 ± 6.7[a]	216.3 ± 6.8[a]	289.1 ± 8.2[b]

Table 4 continued

	9-13 y (n = 4,320)			14-18 y (n =5,339)		
	BS (n = 930)	RTEC consumers (n = 1,536)	OB consumers (n = 1,854)	BS (n = 1,805)	RTEC consumers (n = 1,233)	OB consumers (n = 2,301)
Nutrient parameters	LSM ± LSSE					
Vitamin A (μg RAE)	537.1 ± 27.2[a]	832.9 ± 21.1[b]	613.2 ± 23.0[a]	444.0 ± 21.5[a]	874.6 ± 31.0[b]	542.3 ± 23.2[c]
α Tocopherol (mg)	7.3 ± 0.3[a]	6.5 ± 0.2[b]	6.8 ± 0.2[a, b]	6.4 ± 0.2	6.6 ± 0.3	6.7 ± 0.2
Vitamin K (μg)	60.2 ± 3.1	59.8 ± 5.3	60.2 ± 2.8	55.2 ± 3.3	47.6 ± 3.1	55.1 ± 2.7
Vitamin C (mg)	75.6 ± 4.4[a]	95.7 ± 3.7[b]	84.4 ± 3.4[a]	71.4 ± 4.2[a]	98.4 ± 4.6[b]	85.3 ± 3.7[c]
Thiamin (mg)	1.5 ± 0.03[a]	2.1 ± 0.03[b]	1.5 ± 0.02[a]	1.4 ± 0.03[a]	2.3 ± 0.04[b]	1.5 ± 0.02[a]
Riboflavin (mg)	1.8 ± 0.04[a]	2.8 ± 0.03[b]	2.0 ± 0.03[c]	1.8 ± 0.04[a]	3.0 ± 0.04[b]	2.0 ± 0.04[c]
Niacin (mg)	21.2 ± 0.5[a]	27.0 ± 0.4[b]	20.7 ± 0.3[a]	20.2 ± 0.5[a]	28.7 ± 0.5[b]	19.9 ± 0.4[a]
Vitamin B6 (mg)	1.5 ± 0.1[a]	2.4 ± 0.04[b]	1.5 ± 0.04[a]	1.5 ± 0.1[a]	2.5 ± 0.1[b]	1.4 ± 0.04[a]
Vitamin B12 (μg)	4.3 ± 0.2[a]	6.7 ± 0.2[b]	4.5 ± 0.2[a]	4.2 ± 0.2[a]	7.6 ± 0.2[b]	4.4 ± 0.2[a]
Folate (μg DFE)	327.7 ± 9.1[a]	535.4 ± 11.7[b]	332.2 ± 6.0[a]	320.1 ± 7.4[a]	591.8 ± 12.2[b]	320.5 ± 6.2[a]
Calcium (mg)	883.8 ± 27.0[a]	1150.0 ± 20.5[b]	958.5 ± 20.1[a]	875.6 ± 21.5[a]	1193.0 ± 23.7[b]	944.0 ± 20.7[c]

Table 4 continued

	9-13 y (n = 4,320)			14-18 y (n =5,339)		
	BS (n = 930)	RTEC consumers (n = 1,536)	OB consumers (n = 1,854)	BS (n = 1,805)	RTEC consumers (n = 1,233)	OB consumers (n = 2,301)
Nutrient parameters	LSM ± LSSE					
Phosphorus (mg)	1245.0 ± 21.0[a]	1406.0 ± 15.8[b]	1320.0 ± 15.4[c]	1206.0 ± 16.8[a]	1426.0 ± 18.2[b]	1307.0 ± 16.9[c]
Magnesium (mg)	233.0 ± 3.6[a]	262.6 ± 3.3[b]	236.9 ± 2.7[a]	221.5 ± 3.2[a]	271.7 ± 3.8[b]	235.8 ± 3.1[c]
Iron (mg)	13.5 ± 0.3[a]	20.4 ± 0.3[b]	13.7 ± 0.2[a]	13.5 ± 0.3[a]	22.8 ± 0.4[b]	13.4 ± 0.2[a]
Zinc (mg)	10.8 ± 0.2[a]	14.4 ± 0.2[b]	10.7 ± 0.2[a]	10.7 ± 0.2[a]	15.3 ± 0.3[b]	10.5 ± 0.2[a]
Sodium (mg)	3404.0 ± 54.2[a,b]	3398.0 ± 43.8[a]	3520.0 ± 41.4[b]	3418 ± 53.4[a,b]	3355.0 ± 50.4[a]	3516.0 ± 44.2[b]
Potassium (mg)	2235.0 ± 41.3[a]	2515.0 ± 34.3[b]	2344.0 ± 33.9[a]	2141.0 ± 37.4[a]	2540.0 ± 39.7[b]	2345.0 ± 35.2[c]

Note. NHANES National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; n sample size; kcal kilocalories; g grams; SFA saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; µg micrograms; RAE Retinol Activity Equivalent; mg = milligrams; DFE = Dietary Folate Equivalent; ANOVA = analysis of variance. Values are sample-weighted least-square means (LSM) and least-square standard errors (LSSE). Covariates: Energy intake, gender, ethnicity, age, gender x ethnicity, poverty income ratio (PIR), and physical activity. Covariates for % energy from macronutrients: All above-mentioned covariates, except energy intake. For a given age, means not sharing a same alphabetic character (a, b, c) within a row differ significantly ($p<0.0167$) using Bonferroni's correction; BS vs. RTEC consumers, BS vs. OB consumers, RTEC consumers vs. OB consumers. Composite p values using the F test of ANOVA for nutrient parameters with significant multiple comparisons (a, b, c) within each row for children/adolescents are p 0.0005.

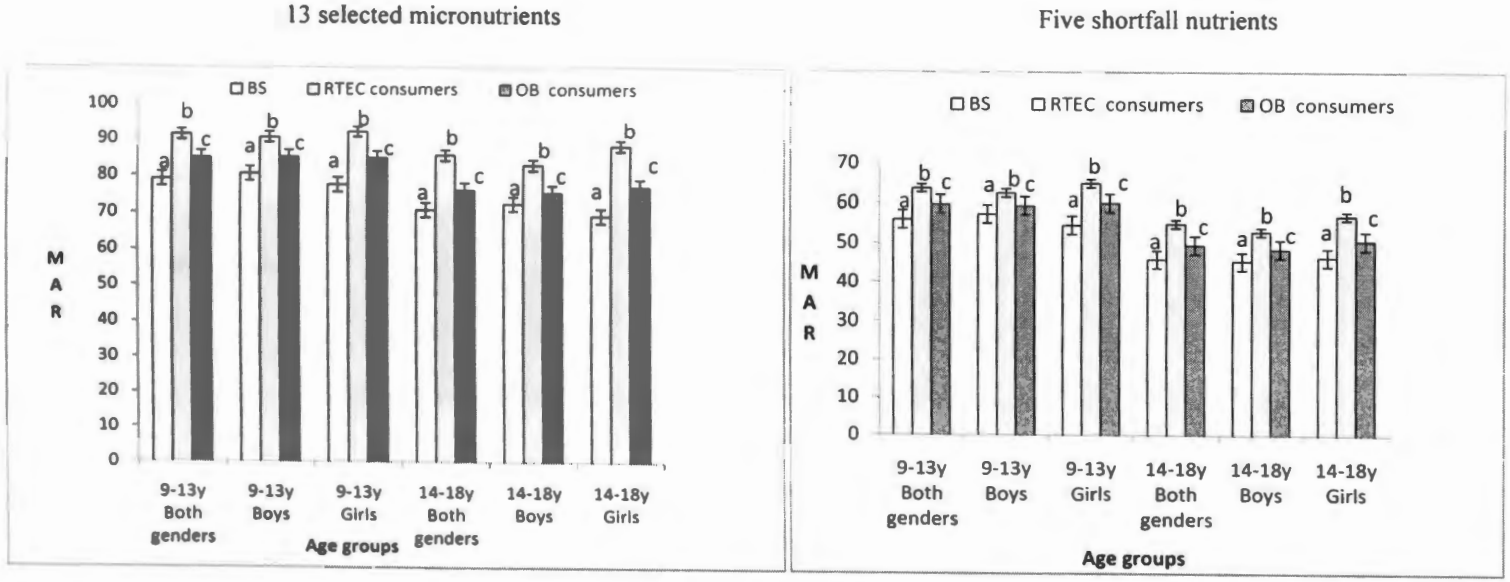

Figure 3. Mean adequacy ratio for nutrient intakes from a reported 24-hour dietary recall by type of breakfast consumption in children (9-13 y) and adolescents (14-18 y): NHANES 1999-2006. *Note.* NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal ; OB = other breakfast; MAR = Mean Adequacy Ratio for nutrients; ANOVA = analysis of variance. Values are sample-weighted least-square means (LSM) and least-square standard errors (LSSE). MAR was computed by calculating the Nutrient Adequacy Ratio (NAR), which was defined as the % of the age-gender specific Recommended Dietary Allowance (RDA) or Adequate Intake (AI) values that met the RDA/AI cut-off. The NARs were truncated at 100 if the value was over the RDA/AI and averaged for the nutrients. 13 selected micronutrients: Vitamins A, E, C, B6, B12, thiamin, niacin, riboflavin, folate, phosphorus, magnesium, iron, zinc. Five shortfall nutrients for children/adolescents: Vitamin E, calcium, magnesium, potassium, dietary fiber. Covariates (both genders): Energy intake, age, gender, ethnicity, gender x ethnicity, poverty income ratio (PIR), and physical activity. Covariates (boys and girls): All above-mentioned covariates, except gender and gender x ethnicity. For a given age, means not sharing a same alphabetic character (a, b, c) differ significantly ($p<0.0167$) using Bonferroni's correction; BS vs. RTEC consumers, BS vs. OB consumers, RTEC consumers vs. OB consumers. Composite p values using the F test of ANOVA for MAR values with significant multiple comparisons (a, b, c) are $p<0.0005$.

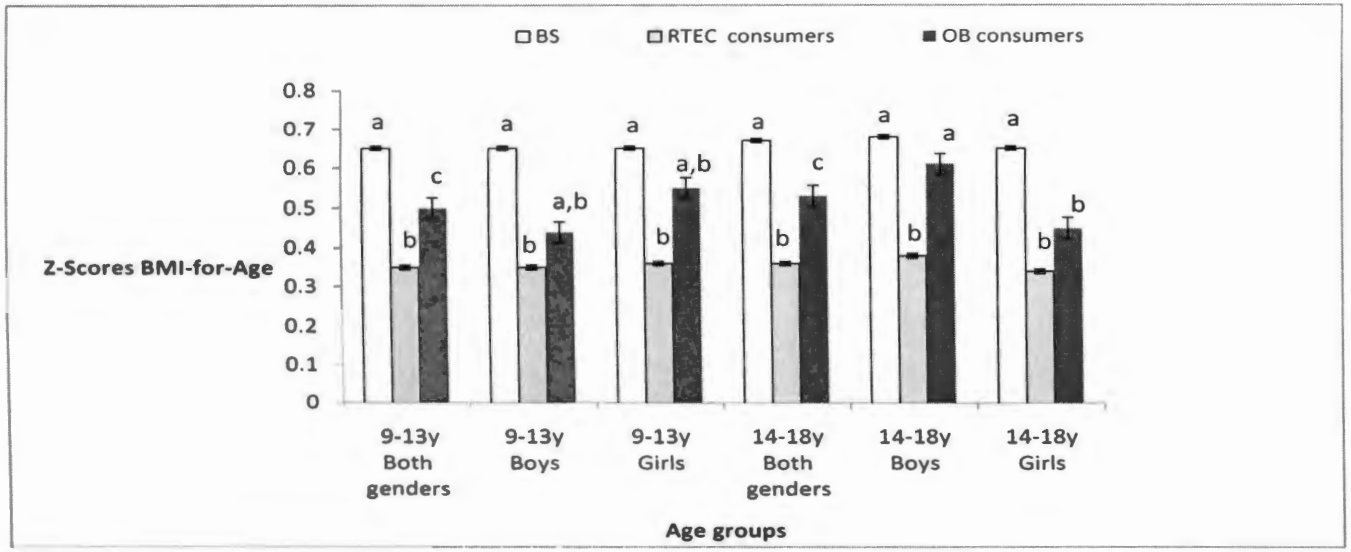

Figure 4. Z-scores of BMI-for-age by type of breakfast consumption in children (9-13y) and adolescents (14-18y): NHANES 1999-2006. *Note.* NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; BMI = body mass index; ANOVA = analysis of variance. Values are sample-weighted least-square means and least-square standard errors. Covariates (both genders): Energy intake, age, gender, ethnicity, gender x ethnicity, physical activity, and poverty income ratio (PIR). Covariates (boys and girls): All above-mentioned covariates, except gender and gender x ethnicity. For a given age, means not sharing a same alphabetic character (a, b, c) differ significantly ($p<0.0167$) using Bonferroni's correction; BS vs. RTEC consumers, BS vs. OB consumers, RTEC consumers vs. OB consumers. Composite p values using the F test of ANOVA for the BMI-for-age z-scores with significant multiple comparisons (a, b, c) are $p<0.0005$.

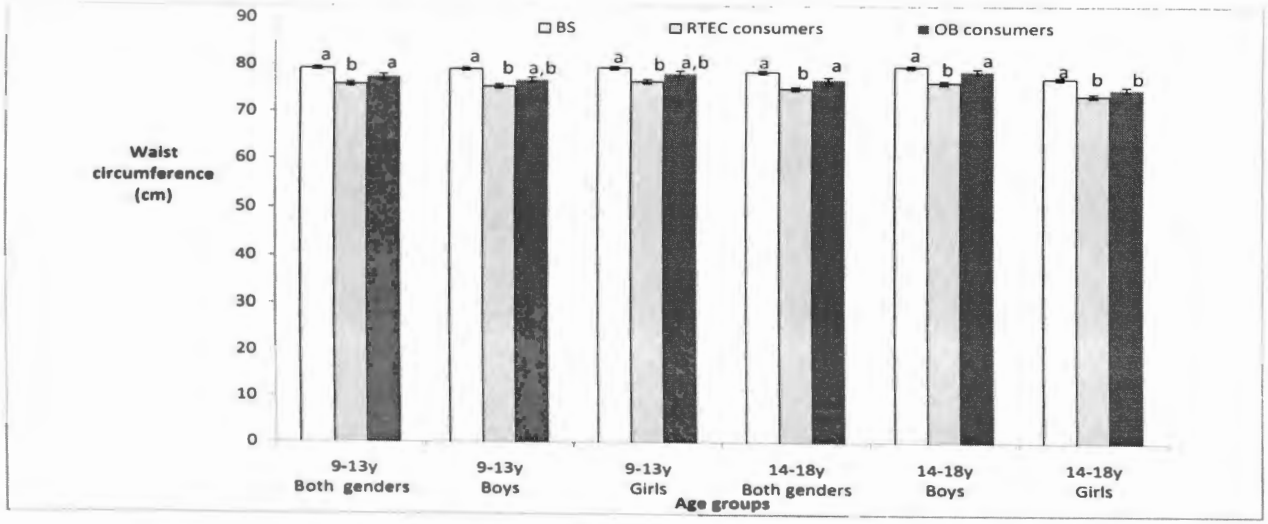

Figure 5. Waist circumference by type of breakfast consumption in children (9-13 y) and adolescents (14-18 y): NHANES 1999-2006. *Note.* NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; ANOVA = analysis of variance. Values are sample-weighted least-square means and least-square standard errors. Covariates (both genders): Energy intake, age, gender, ethnicity, gender x ethnicity, physical activity, and poverty income ratio (PIR). Covariates (boys and girls): All above-mentioned covariates except, gender and gender x ethnicity. For a given age, means not sharing a same alphabetic character (a, b, c) differ significantly ($p<0.0167$) using Bonferroni's correction; BS vs. RTEC consumers, BS vs. OB consumers, RTEC consumers vs. OB consumers. Composite p values using the F test of ANOVA for waist circumference values with significant multiple comparisons (a, b, c) are $p<0.001$.

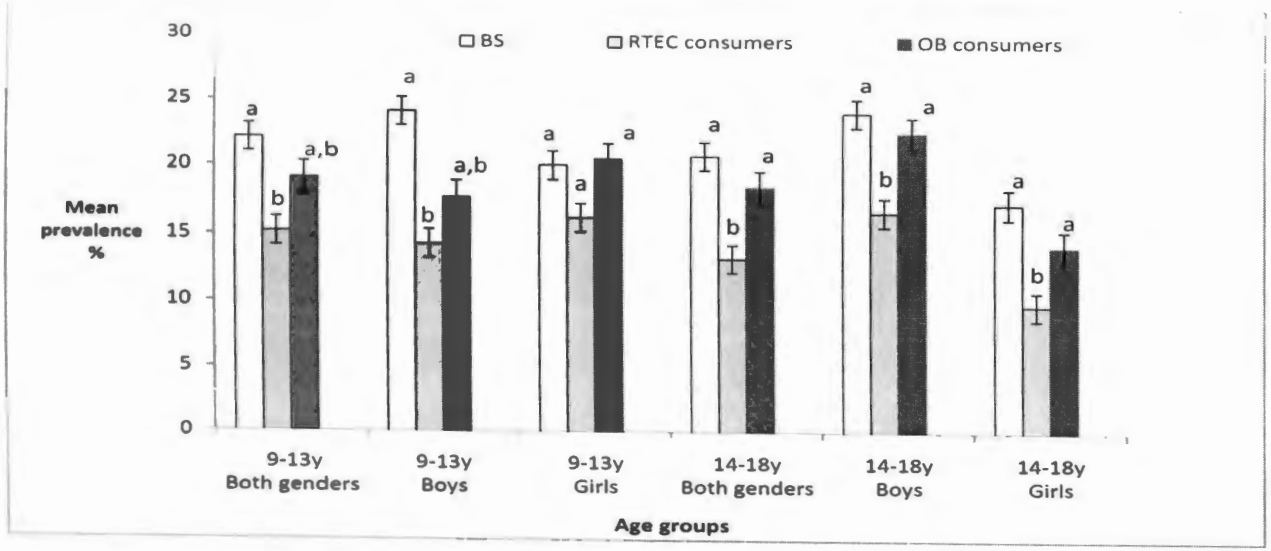

Figure 6. Prevalence of obesity by type of breakfast consumption in children (9-13 y) and adolescents (14-18 y): NHANES 1999-2006. *Note.* NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; ANOVA = analysis of variance. Obesity = body mass index (BMI) ≥ 95th percentile. Values are sample-weighted least-square means and least-square standard errors of a dichotomous variable. Covariates (both genders): Energy intake , age, gender, ethnicity, gender x ethnicity, physical activity, and poverty income ratio (PIR). Covariates (boys and girls): All above-mentioned covariates, except gender and gender x ethnicity. For a given age, means not sharing a same alphabetic character (a, b, c) differ significantly ($p<0.0167$) using Bonferroni's correction; BS vs. RTEC consumers, BS vs. OB consumers, RTEC consumers vs. OB consumers. Composite p values using the F test of ANOVA for obesity prevalence (i.e., mean percents) with significant multiple comparisons (a, b, c) are $p<0.001$.

CHAPTER IV

DOES BREAKFAST SKIPPING AND BREAKFAST TYPE AFFECT ENERGY INTAKE, NUTRIENT INTAKE, NUTRIENT ADEQUACY, AND DIET QUALITY IN YOUNG ADULTS?

NHANES 1999-2002

(STUDY II)

Introduction

Young adulthood (20-39 years of age [y]) is an important period of transition from adolescence into adulthood when individuals begin to live autonomously (Avery, Goldscheider, & Speare, 1992). With increasing responsibility of providing support for new families and/or having hurried lifestyles (Goldscheider & Vanzo, 1989), young adults become vulnerable to unhealthy dietary habits such as skipping of breakfast (Nicklas et al., 1998), relying on fast foods (Pereira et al., 2005), or regularly eating meals outside the home (Clemens, Slawson, & Klesges, 1999). These unhealthy dietary habits could translate into consumption of energy-dense and/or nutrient-poor diets, potentially contributing to the development of overweight obesity and its related metabolic disorders among young adults (Burger, Kern, & Coleman, 2007; Duffey, Gordon-Larsen, Jacobs, Williams, & Popkin, 2007; Ogden et al., 2006; Pereira et al., 2002; Pereira et al.). Therefore, it is crucial to prevent and or correct unhealthy dietary practices in this age group. Nonetheless, few recent studies from the United States (US)

have examined the dietary habits of the young adult population (Burger et al., 2007; Duffey et al., 2007; Pereira et al.; Zizza, Seiga-Riz, & Popkin, 2001).

Eating breakfast is a sound dietary habit for several reasons, the most important being physiological, i.e., the body (especially the brain) needs a metabolic substrate in the form of carbohydrates and amino acids to function optimally after an overnight fast (Wurtman et al., 2003). Yet, breakfast consumption tends to decline with increasing age until young adulthood (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2001-2002). The Bogalusa Heart Study showed that by young adulthood (19-39 y), 37% of the participants skipped breakfast (Nicklas et al., 1998); whereas among adults ($\bar{X}$ = 43.9 y) from a national US survey, it was noted that 20% skipped breakfast (Cho et al., 2003).

In previous studies, it has been reported that breakfast consumers have higher intakes of total energy (Cho et al., 2003; Nicklas et al., 1998), protein, and several micronutrients (Nicklas et al., 1998) than those who skip breakfast. Yet, none of the studies to date has examined the impact of breakfast skipping or consumption on either overall food group intakes or diet quality (using criteria such as the Healthy Eating Index [HEI] scores) (Guenther et al., 2007), or nutrient adequacy (using the Mean Adequacy Ratio [MAR] scores) (Krebs-Smith & Clark, 1989) in young adults. Because people eat foods, and not nutrients, and foods are consumed in combinations (Willett, 1998), evaluation of overall diet quality in conjunction with assessment of nutrient intake and/or nutrient adequacy, seems to be a reasonable approach for dietary evaluation.

While skipping breakfast is a public health concern, the type of breakfast consumed should be also considered when evaluating the overall nutritional consequences of breakfast skipping or nutrient contribution that comes with breakfast consumption. Ready-to-eat cereal (RTEC) is a convenient and palatable breakfast food, and most RTECs are nutrient-dense (since they are fortified with vitamins and minerals) and many are low in fat and/or high in dietary fiber (Anderson & Bridges, 1988; Backstrand, 2002; Johnson et al., 1998; Ready-to-eat Cereals, 2008; Subar et al., 1998a; Whittaker et al., 2001). Therefore, consumption of RTEC at breakfast contributes to better overall nutrient intakes (Anderson & Bridges, 1988; Bachman, Reedy, Subar, Krebs-Smith, 2008; Song et al., 2005; Subar et al.) rather than skipping this meal. However, to date, it is not clear if breakfast foods other than RTECs contribute to favorable nutrient intake profiles or better diet quality. Further, there is limited information comparing energy and nutrient intakes at the breakfast meal and the type of foods consumed at breakfast (Nicklas et al., 1998) especially, when the meal does or does not include an RTEC. Consequently, it is important to compare the nutritional impact of type of breakfast consumed on both nutrient intakes and overall diet quality, particularly, in the young adult population. The objective of this study was to assess the impact of breakfast skipping and type of breakfast consumed (i.e., RTEC vs. other breakfast foods [OB]) on energy/nutrient intake, nutrient adequacy, and diet quality in young adults using the 1999-2002 National Health and Nutrition Examination Survey (NHANES).

Subjects and Methods

Study Design and Population

The NHANES was designed to provide health and nutrition information on participants representing the non-institutionalized US civilian population of all ages (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). The survey used a multistage, stratified sampling design, with over-sampling of participants from certain ethnicities and age groups to ensure their adequate representation (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey). The NHANES involved an in home-interview for demographic and basic health information, as well as a detailed health examination, at the mobile examination center conducted by highly trained examiners and interviewers (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey). The data collection and quality control procedures are available at the NHANES website (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey). The present study combined four years of NHANES cross-sectional data, from 1999-2002, on young adults, 20-39 y ($\bar{X}$ = 29.9 y). Pregnant and/or lactating women (n = 592) and those with unreliable diet recalls (n = 196) (as indicated by the quality and completeness status code used in the dietary interview component) were excluded, resulting in a final sample size of 2,615 young adults. Due to the nature of the analysis (i.e., a secondary data analysis), and the lack of personal identifiers, this study was reviewed and approved in the exempt category by the

Institutional Review Boards of Texas Woman's University, Houston, TX and Baylor College of Medicine, Houston, TX.

Dietary Assessment

The dietary interviewer recorded type and amount of foods consumed by participants in the last 24 hours using a computer-assisted dietary interview (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006; Wright et al., 2007). The computer-assisted dietary interview is a multi-pass method with standardized probes conducted either in person or by telephone with three-dimensional models, pictures of foods, measurement guides, and charts (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey; Wright et al.). Data from a single-day dietary recall, available for the 1999-2002 NHANES, were used for this study. Breakfast consumption was self-reported and included consumption of any food/beverage at a meal reported by the participants as breakfast/brunch or desayuno/almuerzo (Spanish), together designated as 'breakfast' in this study. Breakfast skippers (BS) were defined as those who consumed no foods/beverages at breakfast, excluding water. Ready-to-eat cereal breakfast consumers were defined as those who ate RTEC at breakfast (regardless of other foods beverages consumed at that meal), and OB consumers were defined as those who consumed foods/beverages other than RTEC at breakfast.

Intakes of energy, macro- and micronutrients, and alcohol were obtained/appended using food composition data from the 1999-2000 and 2001-2002

NHANES dietary databases, (Wright et al., 2007), the US Department of Agriculture's (USDA) dietary database (for vitamins A and E) (United States Department of Agriculture's Dietary Database for vitamin A and E, 1999-2000), the Food and Nutrition Database for Dietary Studies (FNDDS, 1.0) (for folate and total sugars) (United States Department of Agriculture's Food and Nutrient Database for Dietary Studies, 1.0), and the My Pyramid Equivalents Database for USDA Survey Food Codes (1.0) (for added sugars) (Friday & Bowman, 2006). Added sugars were defined as caloric sweeteners added to foods/beverages during the processing/preparation stage; examples included raw sugar, high-fructose corn syrup etc., while total sugars included natural sugars in foods/beverages and added sugars. Percent energy intakes from macronutrients and liquid fats/discretionary oils; and those from discretionary solid fats, alcohol, and added sugars were calculated. The latter contribute to discretionary calories, which may be consumed after the basic nutrition needs are met, without exceeding the energy requirements (United States Department of Agriculture's Dietary Guidelines for Americans, 2005). The Nutrient Adequacy Ratio (NAR) for 14 selected micronutrients (i.e., vitamins A, E, and C, thiamin, riboflavin, niacin, vitamin B6, vitamin B12, folate, phosphorus, calcium, magnesium, iron, and zinc) was calculated as the percent of the age-gender specific Recommended Dietary Allowance (RDA) or Adequate Intake (AI) value (Institute of Medicine's Dietary Reference Intakes, 2006) that met the RDA/AI cut-off. The NARs were truncated at 100 if the value was over the RDA/AI, preventing an excess intake of one nutrient from compensating for inadequate intake of other nutrients, and were then

averaged for the 14 micronutrients to obtain the MAR (Krebs-Smith & Clark, 1989). The MAR for 7 shortfall nutrients for adults (i.e., vitamins A, E, and C, calcium, magnesium, potassium, and dietary fiber), as defined by the 2005 Dietary Guidelines for Americans (DGA) (United States Department of Agriculture's Dietary Guidelines for Americans Shortfall Nutrients, 2005), was calculated in the same manner. A conservative score of ≥ 90 was considered as nutritionally adequate for MAR (Krebs-Smith & Clark, 1989).

The HEI-2005 criteria were used to assess the entire day's diet quality scores. The HEI provides a reasonable measure for the evaluation of a day's diet quality in all age groups >2 y (Guenther et al., 2007). Details regarding the development of HEI-2005 criteria are provided elsewhere (Guenther et al.). In short, these criteria included scores for 12 food components, with a total of 100 points (Guenther et al.). Six food components (i.e., total grains, whole grains, total vegetables, dark-green/orange vegetables/legumes, total fruits, and whole fruits) were worth 0–5 points; five food components (i.e., milk, meats/beans, oils, saturated fatty acid [SFA], and sodium) were worth 0–10 points; and one food component (i.e., energy from solid fats, alcoholic beverages, and added sugars [SoFAAS]) was worth 0–20 points. The HEI scores increased proportionately with increasing intakes, except for SFA, sodium, and SoFAAS, for which lower intakes resulted in higher scores. All HEI scores were evenly prorated, except for SFA and sodium, which were prorated from 0-8 and from 8-10 points (with 8 and 10 points representing acceptable and optimal levels, respectively (per the 2005 DGA recommendations) (Guenther et al.). Components and standards for the HEI-2005 scoring

were energy-adjusted on a density basis (per 1,000 kcal). Rating of diet quality (such as good, fair, or poor) based solely on the total HEI-2005 score was not recommended, since a 'fair' overall assessment could mean 'fair' on all components or 'outstanding' on some and 'poor' on others (Guenther et al.). Therefore, individual food component scores from the HEI-2005 were considered important in this study to provide independent information about diet quality (Guenther et al.).

For the breakfast meal exclusively, intakes of energy, percent energy from macronutrients, dietary fiber, cholesterol, micronutrients, and food groups (in g/ounces/teaspoons) were compared between the two types of breakfast consumers. Other breakfast foods consumed at breakfast (excluding RTEC) by both, RTEC and OB consumers were classified using the FNDDS (2.0) (United States Department of Agricultures' Food and Nutrition Database for Dietary Studies, 2.0), and the percent of young adults consuming those OB foods was determined.

Covariates

Food group consumption tends to vary by socioeconomic, demographic, and lifestyle factors (Deshmukh-Taskar et al., 2007; Kourlaba et al., 2008; Yannakoulia, Panagiotakos, Pitsavosm Skounasm, & Stafanadis, 2008). Therefore, demographics (i.e., age, gender, ethnicity, ethnicity x gender, poverty income ratio [PIR]), and marital status), and lifestyle habits (i.e., physical activity, smoking, and alcohol consumption) along with energy intake were treated as covariates. An assessment of multi-collinearity among the above covariates revealed low correlations ($r < \pm 0.4$, $p < 0.05$) between them.

The data for all covariates (except energy and alcohol intake that were obtained from the 24-hour dietary recall) were obtained from self-reported NHANES questionnaires. Ethnicity was defined as self-reported and categorized into non-Hispanic Whites, non-Hispanic Blacks, Mexican-Americans/Hispanics, and Other/Mixed races. The PIR of the households was categorized into groups ranging from <1 (indicating households below the poverty threshold) to ≥ 5. Physical activity was categorized into four groups, 'sedentary', 'light', 'moderate', and 'heavy'. Lifetime smoking status was defined as 'current', 'past', and 'never' smokers.

Statistical Analyses

Statistical Analysis Software ([SAS] 9.2, Cary, North Carolina, 2007 (Statistical Analyses Software, 2007) was used for data analyses. Details of statistical methods are available at the NHANES website (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). Four-year sample-weights were applied to the data to account for unequal probability of selection from over-sampling and for the stratified-multistage probability sample design. Sample-weighted percent ± standard errors (SE) were obtained using PROC SURVEYFREQ. Chi-square test was used to determine the differences among categorical variables. Sample-weighted means and SE were obtained using PROC SURVEYMEAN; the means were compared among three breakfast groups (i.e., BS, RTEC, and OB consumers) using covariate-adjusted analysis of variance (i.e., PROC SURVEYREG). Bonferroni's correction ($p<0.0167$) was used to adjust the significance level for multiple comparisons

for entire day's intake. The traditional cut-off of $p \leq 0.05$ was used for (1) comparing energy/nutrient and food group consumption from the breakfast meal, (2) comparing categorical variables, and (3) for testing Pearson/Spearman correlations among the covariates.

Results

Demographic Characteristics

A higher percent of young adults were OB consumers (58.4%) than being BS (25.1%) or RTEC consumers (16.5%) (see Table 5). Among BS, a higher percent were males (59.6%) than females (40.4%). A higher percent of non-Hispanic Whites appeared to be RTEC consumers (74.1%) than being BS (60.7%) or OB consumers (62.7%); a higher percent of non-Hispanic Blacks appeared to be BS (14.7%) than being RTEC (9.7%) or OB (11.2%) consumers; and a higher percent of Mexican-Americans/Hispanics appeared to be OB consumers (21.9%) than being BS (16.7%) or RTEC consumers (14.0%). Among BS, the percent of young adults with a PIR > 5 appeared to be the lowest (12.3%) than in the other PIR categories. A higher percent of RTEC (57.5%) and OB consumers (57.9%) appeared to be married/cohabiting than BS (49.5%). A higher percent of RTEC and OB consumers appeared to be non-smokers (63.8% and 55.5% respectively) than BS (47.3%). The amount of alcohol consumed was the lowest in RTEC consumers ($\bar{X}$ = 8.6 g/day) and the highest in BS ($\bar{X}$ = 20.5 g day) (see Table 5).

Covariate-adjusted Mean Energy/Nutrient Intakes and Nutrient Adequacy Scores/Day by Type of Breakfast Consumption

Ready-to-eat cereal consumers had a higher total energy intake than BS and OB consumers, and OB consumers had a higher total energy intake than BS (see Table 6). Other breakfast consumers had a higher percent energy intake from protein than BS and RTEC consumers. Ready-to-eat cereal consumers had a higher percent energy intake from carbohydrate than BS and OB consumers; however, BS had a higher percent energy intake from carbohydrate than OB consumers. Ready-to-eat cereal consumers had a higher intake of dietary fiber than BS and OB consumers, and OB consumers had a higher intake of dietary fiber than BS. Percent energy intake from total sugars was lower in OB than RTEC consumers and BS. Percent energy intake from added sugars was higher for BS than RTEC and OB consumers. Other breakfast consumers had a higher percent energy intake from total fat than BS and RTEC consumers. Other breakfast consumers had higher percent energy intakes from SFA and polyunsaturated fatty acids (PUFA) than RTEC consumers. Ready-to-eat cereal consumers had a lower percent energy intake from monounsaturated fatty acids (MUFA) than BS and OB consumers. Cholesterol intake was higher in OB consumers than BS and RTEC consumers, and higher in RTEC consumers than BS. Breakfast skippers had a higher percent energy intake from alcohol than RTEC and OB consumers, and OB consumers had a higher percent energy intake from alcohol than RTEC consumers (see Table 6).

Breakfast skippers had lower intakes of almost all micronutrients examined in this study than RTEC consumers (see Table 6). Ready-to-eat cereal consumers had higher intakes of vitamin A, all B vitamins, calcium, phosphorus, magnesium, iron, zinc, and potassium than OB consumers. Intakes of vitamin A, thiamin, riboflavin, vitamin B12, folate, calcium, phosphorus, magnesium, and potassium were higher in OB consumers than BS, but no differences were noted for vitamins E, C, and B6, niacin, iron, zinc, and sodium between OB consumers and BS (see Table 6).

The NARs (see Figure 7) for the intakes of all selected micronutrients and dietary fiber were higher in RTEC consumers than BS, and were higher for most micronutrients (except vitamin E and phosphorus) than OB consumers. The NARs for the intakes of dietary fiber and all micronutrients examined in this study (except vitamin E) were higher in OB consumers than BS. The total MAR scores for the intakes of selected micronutrients and the 2005 DGA's shortfall nutrients were higher in RTEC consumers than in BS and OB consumers, and higher in OB consumers than BS.

Covariate-adjusted Mean Diet Quality Scores/Day by Type of Breakfast Consumption

Breakfast skippers had lower HEI scores for the intakes of total and whole fruits than RTEC and OB consumers (see Table 7). Other breakfast consumers had a lower HEI score for the intake of whole fruits than RTEC consumers. Other breakfast consumers had a higher HEI score for the intake of dark-green/orange vegetables and legumes than BS. The HEI scores for the intakes of total and whole grains were lower for BS than RTEC and OB consumers, and RTEC consumers had higher HEI scores for the intakes of

total and whole grains than OB consumers. Other breakfast consumers had higher HEI scores for the intake of total and whole grains than BS. Ready-to-eat cereal consumers had a higher HEI score for the intake of milk than BS and OB consumers, and OB consumers had a higher score for the intake of milk than BS. Other breakfast consumers had a higher HEI score for the intake of meat/beans than RTEC consumers. Other breakfast consumers had a lower HEI score for the intake of SFA than RTEC consumers. Ready-to-eat cereal consumers had a higher HEI score for the intake of energy from SoFAAS than BS and OB consumers, and OB consumers had a higher HEI score for intake of energy from SoFAAS than BS. Overall diet quality (i.e., total HEI score) was higher for RTEC consumers than BS and OB consumers and was higher for OB consumers than BS (see Table 7).

Covariate-adjusted Mean Energy/Nutrient Intakes and Food Group Consumption at Breakfast

There were no differences in energy and protein intakes between RTEC and OB consumers (see Table 8). However, RTEC consumers had higher percent energy intakes from carbohydrate and total sugars and a higher intake of dietary fiber than OB consumers. Ready-to-eat cereal consumers had higher intakes of vitamins A and C, all B vitamins, calcium, phosphorus, magnesium, iron, zinc, and potassium than OB consumers. Other breakfast consumers had higher percent energy intakes from total fat, liquid fat, solid fat, SFA, MUFA, PUFA, as well as higher cholesterol and sodium intakes, than RTEC consumers. Ready-to-eat cereal consumers had a higher

consumption of total fruits, whole grains, dairy products, and total sugars than OB consumers. Other breakfast consumers had a higher consumption of vegetables, legumes, meat/poultry/fish, eggs, liquid fat, and solid fat than RTEC consumers (see Table 8).

The contributors of OB foods are depicted in Figure 8. A greater percent of RTEC consumers consumed milk (low-fat, 2%, whole, and flavored)/yogurt, fruits, and 100% fruit juices than OB consumers; whereas a greater percent of OB consumers consumed tea/coffee, breads/rolls, sugars/sweets, sweetened beverages, processed meats, butter/margarine/oils, eggs, cakes/cookies/pies/pastries, quick breads (e.g., muffins), creams/cream substitutes, sauces/gravies, and potatoes/French fries than RTEC consumers.

Discussion

This study is the first to compare nutrient intake, nutrient adequacy (i.e., MAR scores), and diet quality (i.e., HEI-2005 scores) among BS and two types of breakfast consumers (i.e., RTEC and OB) in young adults. The prevalence results for breakfast skipping and consumption for this study are comparable to those reported in the earlier NHANES for young adult individuals (30-39 y), of whom 26% were BS and 74% were breakfast consumers (with only 18.3% consuming an RTEC at breakfast) (Song et al., 2005). In this study, the mean total energy intake/day was higher for RTEC consumers than BS and OB consumers, and OB consumers had a higher mean total energy intake/day than BS. Earlier, Cho et al. (2003) using data from NHANES III reported that the mean energy intakes during the day of RTEC and cooked cereal consumers were

higher than those of skippers, fats/sweets, and fruit/vegetable breakfast consumers, but lower than that of meat/egg breakfast consumers.

Despite the fact that many RTECs are presweetened (i.e., contain added sugars) and their consumption may potentially increase the amounts of total and added sugar intakes per serving, results from the present study in fact showed that BS had a higher mean percent energy intake from added sugars/day than RTEC consumers, although the intake was within the recommendation of < 25% of energy intake (Institute of Medicine's Dietary Reference Intakes, 2006; United States Department of Agriculture's Dietary Guidelines for Americans, 2005). In addition, compared to RTEC and OB consumers BS had a lower mean HEI score for energy from SoFAAS (indicating a higher intake/day) and consumed a higher mean percent energy from alcohol/day. Further, BS also had lower mean intakes for many micronutrients/day compared to RTEC and OB consumers. Skipping of breakfast may potentially lead to an increased intake of energy-dense foods or foods that provide discretionary calories, yet not necessarily meeting the daily energy/nutrient requirements. Further, a higher consumption of added sugars may cause a dilution of nutrients, since foods high in added sugars tend to be low in nutrient density and/or may displace the consumption of healthier foods (Guthrie & Morton, 2000).

Ready-to-eat cereal breakfast consumers had higher mean intakes day for dietary fiber, all B vitamins, and several minerals, such as calcium, phosphorus, magnesium, iron, zinc, and potassium (but not sodium), than BS and OB consumers. Song et al. (2006) found that the percent of adults below the AI level for calcium (1000 mg day) was

higher for non-RTEC than for RTEC consumers. In this study, the mean intakes/day for some micronutrients were higher than the RDA/AI values (Institute of Medicine's Dietary Reference Intakes, 2006) in the RTEC consumers (e.g., vitamin A [122%] and vitamin C [144%], all B vitamins, including folate [204%], calcium [125%], phosphorus [243%], iron [201%], and zinc [179%]). Among all the breakfast groups, the mean intakes/day for vitamin E, magnesium, potassium, and dietary fiber fell below the RDA/AI values (Institute of Medicine's Dietary Reference Intakes) but the mean intakes of all B vitamins, phosphorus, and sodium were higher than the RDA/AI values (Institute of Medicine's Dietary Reference Intakes). The mean nutrient adequacy and diet quality scores/day were all higher in RTEC consumers than BS and OB consumers. Further, only RTEC consumers had a mean nutrient adequacy (i.e., MAR) score close to the cut-off point of 90 (Krebs-Smith & Clark, 1989) for the selected micronutrients. However, the mean MAR score for the 2005 DGA's seven shortfall nutrients (that were identified as nutrients consumed in amounts low enough to be of concern by American adults) (United States Department of Agriculture's Dietary Guidelines for Americans Shortfall Nutrients, 2005) fell below the cut-off point 90 among all the breakfast groups.

The current daily-recommended intake for total fat is between is 20-35% of energy for adults (United States Department of Agriculture's Dietary Guidelines for Americans 2005). All the breakfast groups had a mean percent energy intake from fat day within the recommendation, yet it was the higher in OB consumers ($\bar{X}$ = 33.5%) than in BS ($\bar{X}$ = 31%) and RTEC consumers ($\bar{X}$ = 30.1%). In an earlier study, Song et al. (2005)

reported that among adults, RTEC consumers consumed 30% of energy from total fat/day vs. 34% consumed by the non-RTEC group. Further, the present study also found that the mean percent energy intake from discretionary solid fat/day was higher in OB consumers than in BS and RTEC consumers. The mean percent energy intake from SFA/day was greater than the recommended DGA value of <10% (United States Department of Agriculture's Dietary Guidelines for Americans) among all breakfast groups, but was the highest among OB consumers ($\bar{X}$ = 11.1%). Additionally, the mean cholesterol intake/day in OB consumers was higher than the 2005 DGA's recommendation ($\bar{X}$ = 342 mg/day vs. < 300 mg/day respectively) (United States Department of Agriculture's Dietary Guidelines for Americans). The mean percent energy intakes/day from MUFA and PUFA were lower in RTEC consumers than OB consumers, and this could be a result of the lower total fat intake during the day by the RTEC consumers.

Other breakfast consumers had a higher mean percent energy intake/day from protein than BS and RTEC consumers. No differences in the mean intakes/day for vitamins E, C, B6, niacin, iron, zinc, and sodium were noted between OB consumers and BS. Other breakfast consumers had lower mean intakes/day of most micronutrients (except vitamins E and C, and sodium) than RTEC consumers. Compared to RTEC consumers, OB consumers may be consuming fewer nutrient-dense foods at breakfast and at other meals, which may result in them having lower micronutrient intakes and lower overall scores for both nutrient adequacy and diet quality. Breakfast foods (other than RTEC), unless chosen prudently, are often high in total fat, SFA, cholesterol, trans

fat, and may provide a surplus of discretionary calories (including added sugars) in the diet. Moreover, even for the breakfast meal itself, OB consumers from this study reported higher mean intakes of total fat and discretionary solid fat, sodium, cholesterol, eggs, and meat products than RTEC consumers. An assessment of the non-RTEC breakfast foods consumed revealed that a higher percent of OB consumers consumed sugars/sweets, sweetened beverages, processed meats, and cakes/cookies/pies than RTEC consumers.

The role of dietary fat or carbohydrates in the long-term management of overweight/obesity is not clear (Hession, Rolland, Kulkarni, Wise, & Broom, 2009; Klein, 2004). Further, in obese adolescents, a high-fat breakfast (60-65% of energy) was noted to cause a smaller postprandial increase in plasma peptide YY (a hormone, which decreases food intake), and a higher subsequent lunch intake than in the normal weight controls (Misra, Tsai, Mendes, Miller, & Klibanski, 2009). In the same study, a high-carbohydrate breakfast (60-65% of energy) was noted to cause greater increases in plasma ghrelin (a hormone, which increases hunger) and a higher subsequent lunch intake in obese adolescents than in the controls (Misra et al., 2009). Due to these inconclusive results, it becomes more important to further investigate if OB consumers (due to their overall lower nutrient/diet quality scores) than RTEC consumers, are more prone to overweight/obesity and its related metabolic disorders. In addition, whether and/or how the consumption of an RTEC breakfast (that contributed 71.9% of energy from carbohydrate at the breakfast meal in this study) affects postprandial changes in

hormones (such as ghrelin), subsequent food intake, nutrient/diet quality, and appetite regulation is not understood. Further investigation in this area is essential.

At the breakfast meal, RTEC consumers had higher mean intakes of fruits, whole grains, total sugars, dietary fiber, dairy products, and several micronutrients than OB consumers. The present findings underscore the importance of consuming a healthy breakfast, such as an RTEC, for its several nutritional benefits. The higher mean nutrient adequacy score for micronutrients for RTEC consumers than BS and OB consumers may be attributed to the fact that about 92% of RTECs available are fortified with vitamins and minerals (Ready-to- eat Cereals, 2008). Ready-to-eat cereal consumption may also improve calcium intake by the addition of calcium-rich dairy foods (e.g., milk/yogurt) to it. Song et al. (2006) reported that the average calcium intake at breakfast was seven times greater when the RTEC was consumed with milk than when consumed without milk. In this study, 98% of the RTEC consumers reported consumption of dairy foods (i.e., milk [all types] and yogurt) at breakfast. Consumption of RTEC may also help to boost the intake of whole grains and dietary fiber, both of which are consumed at levels below the recommended intakes by Americans (United States Department of Agriculture's Dietary Guidelines for Americans, 2005; United States Department of Agriculture's Dietary Guidelines for Americans Shortfall Nutrients, 2005). For example, one serving of RTEC may contribute to <1% to up to 60% of the Daily Value (25 g/day) for dietary fiber (e.g., bran-based RTEC with extra fiber may provide 15g of dietary fiber per serving). Lastly, RTEC consumers from this study had higher mean HEI scores for

whole fruits, whole grains, and milk (indicating higher intakes/day), as well as for SFA, and energy from SoFAAS (indicating lower intakes/day) than BS and OB consumers, suggesting that RTEC consumers tend to choose healthier foods and consume lower fat and/or discretionary calories. These results thus indicate that RTEC consumers tend to have overall healthy food consumption habits than BS and OB consumers.

Limitations

Due to the cross-sectional nature of the present study and use of a self-reported measure to assess breakfast consumption and nutrient intakes, causality cannot be determined (Willett, 1998). Also, a single 24-hour dietary recall (as used in the present study) may not represent regular breakfast habits of the population. In addition, the nutrients contributed by vitamin-mineral supplements were not considered in this study. It may also be possible that some of the OB foods (including milk) consumed by RTEC consumers in addition to consuming an RTEC at breakfast could have favorably influenced the nutrient intakes /diet quality.

Some inherent limitations of the HEI criteria exist (Guenther et al., 2007), (e.g., its validity for specific ethnic groups in the US is not established; the criteria do not directly capture excess intakes of total fat and cholesterol (yet, this study examined them separately), *trans* fats, oils, refined grains, or meat. Furthermore, the recommendations for some food groups (e.g., meat/beans and milk) in the HEI when expressed per 1,000 kilocalories vary more than the other food groups. An example of a discrepancy in the density standards of the HEI criteria is reflected in the fact that women are allowed the

lowest discretionary calorie allowance due to their lower suggested energy intakes, despite their high nutrient needs (Guenther et al.).

Conclusions

Efforts to lower the prevalence of breakfast skipping among young adults are needed. Nutrition professionals should encourage the consumption of a healthy breakfast (e.g., one that includes an RTEC), especially among the young adult population. Future studies comparing the impact of breakfast skipping and type of breakfast consumed on nutrient intakes and diet quality should incorporate a longitudinal study design, and/or multiple days of dietary assessment, as well as an examination of weight status/metabolic measures.

Table 5

Demographic Characteristics of Young Adults (20-39 y) by Type of Breakfast Consumption: NHANES 1999-2002

Demographics	BS	RTEC consumers	OB consumers
Sample size (n)	646	403	1,556
Sample size** % ± SE	25.1 ± 1.1	16.5 ± 1.2	58.4 ± 1.3
Age (y)* Mean ± SE	28.4 ± 0.2[a]	29.6 ± 0.3[b]	30.6 ± 0.3[c]
Gender** % ± SE			
Males	59.6 ± 2.0	50.1 ± 2.3	50.5 ± 1.2
Females	40.4 ± 2.0	49.9 ± 2.2	49.5 ± 1.2
Column p value	p<0.0001	NS	NS
Ethnicity** % ± SE			
Non-Hispanic Whites	60.7 ± 3.2	74.1 ± 2.2	62.7 ± 2.3
Non-Hispanic Blacks	14.7 ± 1.6	9.7 ± 1.3	11.2 ± 1.4
Mexican-Americans/Hispanics	16.7 ± 3.1	14.0 ± 1.9	21.9 ± 2.5
Other/Mixed Races	7.9 ± 1.6	2.2 ± 0.8	4.2 ± 0.8
Column p value	p<0.0001	p<0.0001	p<0.0001

Table 5 continued

Demographics	BS	RTEC consumers	OB consumers
PIR* % ± SE			
< 1	19.9 ± 1.9	13.5 ± 2.0	16.8 ± 1.5
≥ 1 and < 2	26.3 ± 2.7	21.4 ± 2.5	24.5 ± 1.8
≥ 2 and < 3	16.8 ± 1.8	17.0 ± 3.6	17.7 ± 1.7
≥3 and < 5	24.7 ± 2.3	25.3 ± 2.5	24.3 ± 1.9
≥5	12.3 ± 2.2	22.8 ± 3.5	16.8 ± 1.6
Column p value	p<0.001	NS	p<0.005
Marital status** % ± SE			
Never married	41.2 ± 2.9	34.3 ± 2.4	32.3 ± 2.0
Married/ Cohabiting	49.5 ± 2.6	57.5 ± 2.7	57.9 ± 2.0
Divorced/Widowed/ Separated	9.2 ± 1.1	8.2 ± 1.8	9.9 ± 1.0
Column p value	p<0.0001	p<0.0001	p<0.0001
Smoking status** % ± SE			
Never smokers	47.3 ± 3.1	63.8 ± 3.0	55.5 ± 1.8
Past smokers	9.4 ± 1.2	11.6 ± 1.4	15.8 ± 1.2

Table 5 continued

Demographics	BS	RTEC consumers	OB consumers
Smoking status % ± SE			
Current smokers	43.2 ± 2.9	24.6 ± 2.8	28.7 ± 1.7
Column p value	p<0.0001	p<0.0001	p<0.0001
Alcohol consumption (g/day)**¶ Mean ± SE	20.5 ± 3.7[a]	8.6 ±1.7[b]	11.9 ± 1.2[c]
Physical activity % ± SE			
Sedentary	22.6 ± 1.8	22.9 ± 2.2	20.4 ± 1.2
Light	48.4 ± 2.2	46.3 ± 3.2	47.2 ± 1.4
Moderate	18.9 ± 1.8	22.5 ± 2.4	20.3 ± 1.6
Heavy	10.1 ± 1.6	8.3 ± 1.2	12.1 ± 1.0
Column p value	p<0.0001	p<0.0001	p<0.0001

Note. NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; PIR = poverty income ratio. Values are sample-weighted percents (%) ± standard errors (SE) for categorical variables or sample-weighted means ± SE for continuous variables. Column percents add to 100 and are indicated with p values in columns from chi-square test. Row percents for sample size, and for all other demographic variables (*data not shown*) are also significant at p<0.0001 from chi-square test. For categorical variables (i.e., percents), **,* indicate overall chi-square, with **p≤ 0.0001 and *p=0.05 (marginal significance) respectively. For continuous variables, means not sharing a same alphabetic character (a, b, c) within a row differ significantly (p<0.0167); BS vs. RTEC consumers, BS vs. OB consumers, RTEC consumers vs. OB consumers. Composite p values using the F test of ANOVA for demographic characteristics with significant multiple comparisons (a, b, c) within a row are **p<0.0001and *p<0.05. ¶Covariates: Energy intake, ethnicity, gender, gender x ethnicity, age, PIR, smoking status, physical activity, and marital status.

Table 6

Energy and Nutrient Intakes from a Reported 24-hour Dietary Recall by Type of Breakfast Consumption in Young Adults (20-39 y): NHANES 1999-2002

	BS (n = 646)	RTEC consumers (n = 403)	OB consumers (n = 1,566)
Nutrient parameters		Mean ± SE	
Energy (kcal)***	2284 ± 58[a]	2670 ± 57[b]	2464 ± 34[c]
Protein (% energy)**	13.9 ± 0.2[a]	14.6 ± 0.2[a]	15.0 ± 0.2[b]
Carbohydrate (% energy)***	51.5 ± 0.7[a]	55.2 ± 0.6[b]	49.9 ± 0.5[c]
Dietary fiber (g)***	11.7 ± 0.4[a]	19.6 ± 0.6[b]	15.5 ± 0.3[c]
Total sugars (% energy)***	27.8 ± 0.9[a]	27.4 ± 0.7[a]	24.8 ±0.5[b]
Added sugars (% energy)***	22.4 ± 0.8[a]	17.7 ± 0.6[b]	17.2 ± 0.6[b]
Total fat (% energy)***	31.0 ± 0.4[a]	30.1 ± 0.6[a]	33.5 ± 0.3[b]
Liquid fat (oil) (% energy)	6.4 ± 0.3	6.4 ± 0.4	6.7 ± 0.2
Solid fat (% energy)***	18.0 ± 0.4[a]	17.4 ± 0.5[a]	19.8 ± 0.3[b]
SFA (% energy)**	10.3 ± 0.2[a,b]	10.3 ± 0.2[a]	11.1 ± 0.1[b]
MUFA (% energy)***	11.8 ± 0.2[a]	11.1 ± 0.2[b]	12.6 ± 0.1[a]
PUFA (% energy)**	6.2 ± 0.2[a,b]	6.1 ± 0.2[a]	6.8 ± 0.1[b]
Cholesterol (mg)***	242.0 ± 11.0[a]	258.1 ± 9.8[b]	341.9 ± 7.3[c]

Table 6 continued

Nutrient parameters	BS (n = 646)	RTEC consumers (n = 403)	OB consumers (n = 1,566)
	Mean ± SE		
Alcohol (% energy)* **	4.7 ± 0.5[a]	1.9 ± 0.3[b]	2.9 ± 0.2[c]
Vitamin A (μg RAE)* **	395.0 ± 16.2[a]	977.8 ± 29.8[b]	619.2 ± 29.1[c]
Vitamin E (mg αT)* **	5.8 ± 0.2[a]	9.0 ± 0.3[b]	7.6 ± 0.2[a,b]
Vitamin C (mg)*	73.1 ± 6.1[a]	118.7 ± 6.8[b]	97.1 ± 3.7[a,b]
Thiamin (mg)* **	1.4 ± 0.04[a]	2.5 ± 0.1[b]	1.6 ± 0.04[c]
Riboflavin (mg)* **	1.6 ± 0.1[a]	3.2 ± 0.1[b]	2.1 ± 0.04[c]
Niacin (mg)* **	21.5 ± 0.6[a]	33.3 ± 0.8[b]	24.1 ± 0.4[a]
Vitamin B6 (mg)* **	1.6 ± 0.1[a]	2.9 ± 0.1[b]	1.8 ± 0.03[a]
Vitamin B12 (μg)* **	4.2 ± 0.1[a]	7.5 ± 0.5[b]	5.3 ± 0.2[c]
Folate (μg) DFE* **	220.0 ± 14.7[a]	814.7 ± 42.5[b]	312. 8 ± 12.0[c]
Calcium (mg)* **	709.0 ± 25.1[a]	1251.8 ± 39.2[b]	915.1 ± 25.7[c]
Phosphorus (mg)* **	1188.6 ± 26.6[a]	1704.3 ± 40.9[b]	1441.5 ± 21.4[c]

Table 6 continued

	BS (n = 646)	RTEC consumers (n = 403)	OB consumers (n = 1,566)
Nutrient parameters		Mean ± SE	
Magnesium (mg)***	237.5 ± 5.9[a]	353.4 ± 9.0[b]	291.8 ± 4.7[c]
Iron (mg)***	12.5 ± 0.4[a]	26.1 ± 0.7[b]	14.9 ± 0.3[a]
Zinc (mg)***	10.8 ± 0.3[a]	17.0 ± 0.5[b]	12.2 ± 0.2[a]
Sodium (mg)	3382.3 ± 73.5	4109.2 ± 76.8	3788.3 ± 73.2
Potassium (mg)***	2223.3 ± 45.9[a]	3208.8 ± 69.9[b]	2802.4 ± 40.1[c]

Note. NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; n = sample size; RAE = Retinol Activity Equivalent; αT = α-Tocopherol; DFE = Dietary Folate Equivalent; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; ANOVA = analysis of variance. Values are sample-weighted means ± standard errors (SE). Covariates for nutrients: Energy intake, ethnicity, gender, gender x ethnicity, age, poverty income ratio (PIR), smoking status, physical activity, marital status, and alcohol intake. Total energy intake and % energy intake from macronutrients adjusted for all above-mentioned covariates except energy intake, and also, except alcohol intake for calculating % energy intake from alcohol. Means not sharing a same alphabetic character (a, b, c) within a row differ significantly ($p < 0.0167$) using Bonferroni's correction; BS vs. RTEC consumers, BS vs. OB consumers, RTEC consumers vs. OB consumers. Composite p values using the F test of ANOVA for nutrient parameters with significant multiple comparisons (a, b, c) within each row are ***$p < 0.0001$, ** $p < 0.005$, and *$p < 0.05$.

Table 7

Diet Quality Scores from a Reported 24-hour Dietary Recall by Type of Breakfast Consumption in Young Adults (20-39 y): NHANES 1999-2002

	BS (n = 646)	RTEC consumers (n = 403)	OB consumers (n = 1,566)
HEI food components (Range for scores)	HEI component scores: Mean ± SE		
HEI 1 : Total fruits (includes 100% juices)*** (0-5)	1.1 ± 0.1[a]	2.0 ± 0.1[b]	1.8 ± 0.1[b]
HEI 2 : Whole fruits (not juices)*** (0-5)	0.8 ± 0.1[a]	1.8 ± 0.1[b]	1.4 ± 0.1[c]
HEI 3 : Total vegetables (0-5)	2.7 ± 0.1	2.7 ± 0.1	2.8 ± 0.1
HEI 4 : Dark green/ orange vegetables and legumes* (0-5)	0.7 ± 0.1[a]	1.04 ± 0.1[a,b]	1.1 ± 0.06[b]
HEI 5 : Total grains*** (0-5)	3.8 ± 0.1[a]	4.5 ± 0.1[b]	4.2 ± 0.04[c]
HEI 6 : Whole grains*** (0-5)	0.3 ± 0.1[a]	1.5 ± 0.1[b]	0.6 ± 0.1[c]
HEI 7 : Milk*** (0-10)	3.8 ± 0.2[a]	7.0 ± 0.2[b]	4.7 ± 0.1[c]
HEI 8 : Meat/ Beans** (0-10)	7.9 ± 0.1[a,b]	7.5 ± 0.2[a]	8.1 ± 0.1[b]
HEI 9 : Oils (0-10)	4.8 ± 0.2	5.0 ± 0.2	5.1 ± 0.1
HEI 10 : SFA** (0-10)	6.3 ± 0.2 [a,b]	6.5 ± 0.2[a]	5.7 ± 0.1[b]

Table 7 continued

	BS (n = 646)	RTEC consumers (n = 403)	OB consumers (n = 1,566)
HEI food components (Range for scores)	HEI component scores: Mean ± SE		
HEI 11 : Sodium (0-10)	4.7 ± 0.2	4.3 ± 0.2	4.4 ± 0.1
HEI 12 : Calories from SoFAAS*** (0- 20)	5.0 ± 0.3[a]	8.5 ± 0.4[b]	7.2 ± 0.3[c]
Total score*** (0- 100)	41.8 ± 0.7[a]	52.1 ± 0.7[b]	46.9 ± 0.5[c]

Note. NHANES National Health and Nutrition Examination Survey; HEI = Healthy Eating Index; BS = breakfast skippers; RTEC – ready-to-eat cereal; OB = other breakfast; n = sample size; SFA = saturated fatty acids; SoFAAS = solid fats, alcohol, and added sugars; ANOVA analysis of variance. Values are sample-weighted means ± standard errors (SE). Covariates: Ethnicity, gender, gender x ethnicity, age, poverty income ratio (PIR), smoking status, marital status, and physical activity. Means not sharing a same alphabetic character (a, b, c) within a row differ significantly ($p<0.0167$) using Bonferroni's correction; BS vs. RTEC consumers, BS vs. OB consumers, RTEC consumers vs. OB consumers. Composite p values using the F test of ANOVA for diet quality (HEI) scores with significant multiple comparisons (a, b, c) within each row are ***p· 0.0001, ** p· 0.005, and *p· 0.05.

Table 8

Energy, Nutrient, and Food Group Intakes at Breakfast from a Reported 24-hour Dietary Recall in Young Adults (20- 39 y): NHANES 1999-2002

	RTEC consumers (n = 403)	OB consumers (n = 1,566)
Nutrient parameters	Mean ± SE	
Energy (kcal)	468 ± 14	515 ± 14
Protein (% energy)	13.4 ± 0.3	13.4 ± 0.3
Carbohydrate (% energy)***	71.9 ± 0.8[a]	55.0 ± 1.9[b]
Dietary fiber (g)***	4.6 ± 0.3[a]	3.0 ± 0.2[b]
Total sugars (% energy)***	36.8 ± 1.0[a]	30.1 ± 0.6[b]
Added sugars (% energy)	17.7 ± 0.8	18.2 ± 0.8
Total fat (% energy)***	18.3 ± 0.7[a]	34.2 ± 0.7[b]
Liquid fat (oil) (% energy)***	1.4 ± 0.2[a]	3.2 ± 0.3[b]
Solid fat (% energy)***	12.1 ± 0.5[a]	23.4 ± 0.7[b]
SFA (% energy)***	7.7 ± 0.3[a]	11.0 ± 0.2[b]
MUFA (% energy)***	5.6 ± 0.2[a]	11.5 ± 0.3[b]
PUFA (% energy)***	2.6 ± 0.2[a]	5.6 ± 0.1[b]

Table 8 continued

	RTEC consumers (n = 403)	OB consumers (n = 1,566)
Nutrient parameters	Mean ± SE	
Cholesterol (mg)* **	39.8 ± 5.0[a]	127.4 ± 5.9[b]
Vitamin A (µg RAE)* **	401.1 ± 14.1[a]	183.4 ± 10.0[b]
Vitamin E (mg αT)	1.9 ± 0.3	1.6 ± 0.1
Vitamin C (mg)* **	41.0 ± 3.3[a]	25.8 ± 1.5[b]
Thiamin (mg)* **	0.9 ± 0.03[a]	0.4 ± 0.02[b]
Riboflavin (mg)* **	1.3 ± 0.05[a]	0.6 ± 0.02[b]
Niacin (mg)* **	10.4 ± 0.5[a]	4.6 ± 0.2[b]
Vitamin B6 (mg)* **	1.2 ± 0.06[a]	0.4 ± 0.02[b]
Vitamin B12 (µg)* **	2.9 ± 0.2[a]	1.1 ± 0.06[b]
Folate (µg) DFE* **	519.3 ± 39.2[a]	117.1 ± 3.7[b]
Calcium (mg)* **	374.7 ± 16.6[a]	239.8 ± 11.7[b]
Phosphorus (mg)* **	404.8 ± 16.5[a]	347.5 ± 12.3[b]

Table 8 continued

	RTEC consumers (n = 403)	OB consumers (n = 1,566)
Nutrient parameters	Mean ± SE	
Magnesium (mg)* **	89.7 ± 3.5[a]	64.9 ± 2.6[b]
Iron (mg)* **	11.6 ± 0.7[a]	3.6 ± 0.2[b]
Zinc (mg)* **	5.6 ± 0.3[a]	2.4 ± 0.1[b]
Sodium (mg)* **	597.1 ± 22.4[a]	807.4 ± 27.4[b]
Potassium (mg)* **	765.8 ± 26.1[a]	657.4 ± 21.5[b]
Food groups		
Total fruits (# of cup equivalents)*	0.4 ± 0.04[a]	0.3 ± 0.02[b]
Total vegetables (# of cup equivalents)**	0.05 ± 0.02[a]	0.3 ± 0.05[b]
Legumes (# of cup equivalents)*	0.01 ± 0.002[a]	0.03 ± 0.006[b]
Total grains (# of ounce equivalents)	1.8 ± 0.08	2.0 ± 0.07
Whole grains (# of ounce equivalents)* **	0.7 ± 0.04[a]	0.2 ± 0.02[b]
Dairy products (# of cup equivalents)* **	0.9 ± 0.04[a]	0.5 ± 0.03[b]

Table 8 continued

	RTEC consumers (n = 403)	OB consumers (n = 1,566)
Food groups	Mean ± SE	
Meat/Poultry/ Fish (# of ounce equivalents)* **	0.1 ± 0.03[a]	0.8 ± 0.09[b]
Eggs (# of ounce equivalents)* **	0.1 ± 0.03[a]	0.4 ± 0.03[b]
Liquid fat (oil) (g)* **	0.8 ± 0.1[a]	2.2 ± 0.2[b]
Solid fat (g)* **	6.9 ± 0.4[a]	15.5 ± 0.6[b]
Added sugars (g)	20.3 ± 1.0	20.7 ± 0.9
Total sugars (g)* **	42.7 ± 1.7[a]	33.7 ± 1.0[b]

Note. NHANES = National Health and Nutrition Examination Survey; RTEC = ready-to-eat cereal; OB = other breakfast; g = grams; mg = milligrams; RAE = Retinol Activity Equivalent; αT = α-Tocopherol; DFE = Dietary Folate Equivalent; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids. Values are sample-weighted means ± standard errors (SE). Covariates for nutrients: Energy intake, ethnicity, gender, gender x ethnicity, age, poverty income ratio (PIR), smoking status, physical activity, marital status, and alcohol intake. Total energy intake and % energy intake from macronutrients adjusted for all above covariates except energy intake. Means not sharing a same alphabetical character (a, b) within a row differ significantly at ***$p \leq 0.0001$, **$p < 0.005$, and *$p < 0.05$.

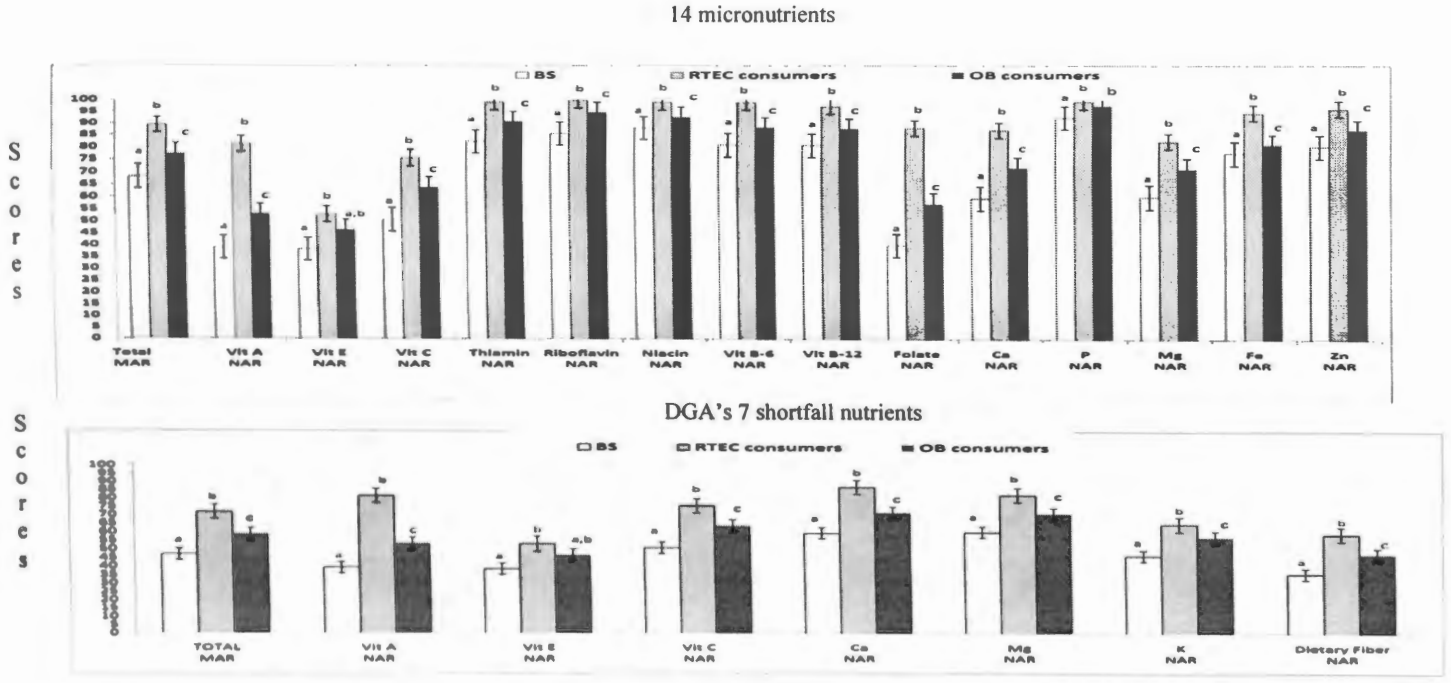

Figure 7. Mean adequacy ratio for nutrient intakes from a reported 24-hour dietary recall by type of breakfast consumption in young adults (20-39 y): NHANES 1999-2002. *Note.* NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; MAR = Mean Adequacy Ratio; NAR = Nutrient Adequacy Ratio; DGA = Dietary Guidelines for Americans; Vit = vitamin; Ca = calcium; P = phosphorus; Mg = magnesium; Zn = zinc; Fe = iron; K = potassium; ANOVA = analysis of variance. Values are sample-weighted means ± standard errors (SE). NARs were calculated as the % of the age-gender specific Recommended Dietary Allowance (RDA) or Adequate Intake (AI) values that met the cut-off. The NARs were truncated at 100 if the value was over the RDA/AI cut-off and averaged for the nutrients to compute the MAR. Covariates: Energy intake, ethnicity, gender, gender x ethnicity, age, poverty income ratio (PIR), smoking status, marital status, physical activity, and alcohol consumption. Means not sharing a same alphabetic character (a, b, c) differ significantly ($p<0.0167$) using Bonferroni's correction; BS vs. RTEC consumers, BS vs. OB consumers, RTEC consumers vs. OB consumers. Composite p values using the F test of ANOVA for MAR/NAR values with significant multiple comparisons (a, b, c) are $p<0.0001$, except for vitamin E, the composite p value was $p<0.005$.

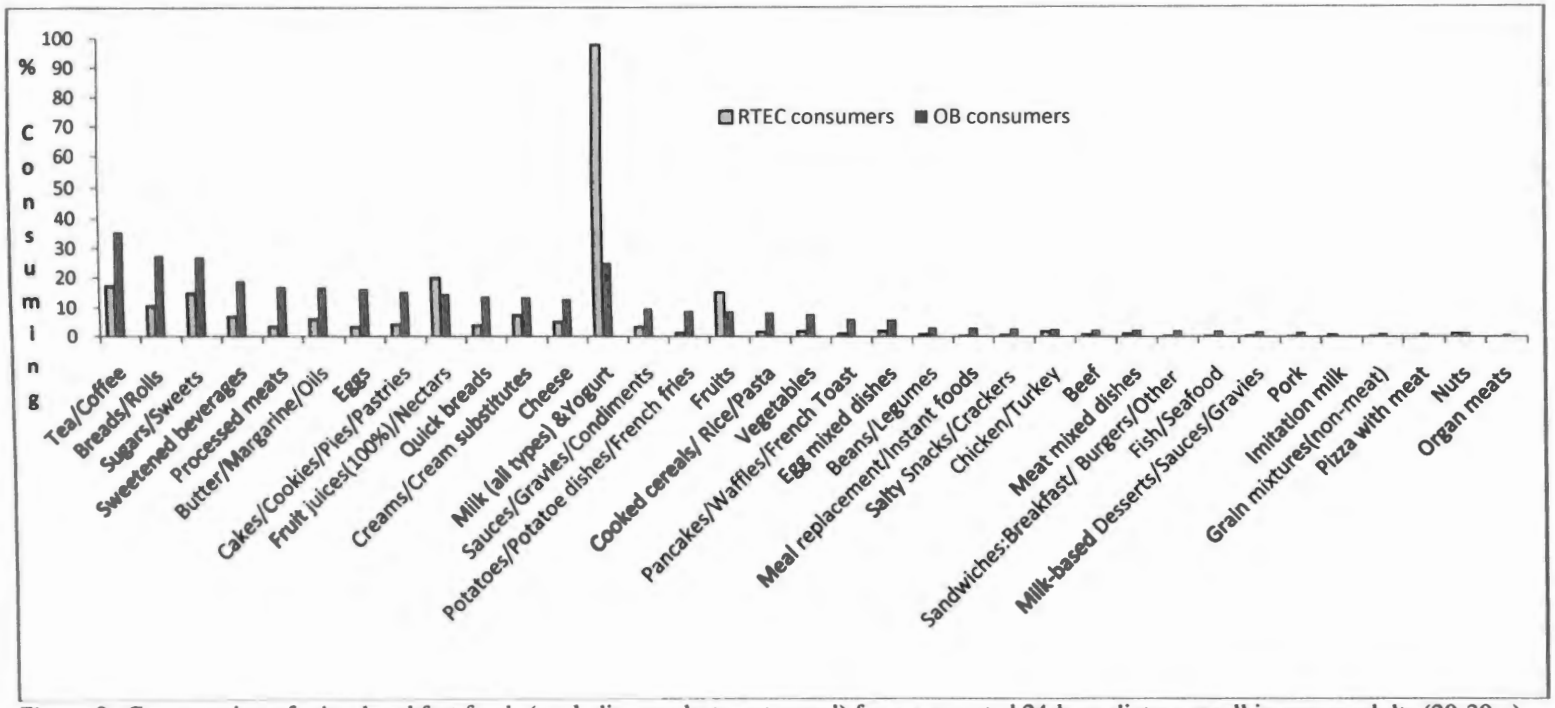

Figure 8. Consumption of other breakfast foods (excluding ready-to-eat cereal) from a reported 24-hour dietary recall in young adults (20-39 y): NHANES 1999-2002. *Note.* NHANES = National Health and Nutrition Examination Survey; RTEC = ready-to-eat cereal; OB = other breakfast foods. Values are sample-weighted percents that indicate % of RTEC and OB consumers consuming other breakfast foods. Other breakfast food examples: **Breads/Rolls:** Bagels, breads, non-sweet rolls; **Sugars/Sweets:** Sugars, sweets/candies, syrups, sweet toppings, jams, jellies; **Sweetened beverages:** Non-alcoholic beverages, soft drinks, fruit drinks; **Processed meats:** Bacon, sausages, ham, bologna, frankfurters; **Quick breads:** Biscuits, muffins, sweet rolls, tortillas; **Milk (all types)/Yogurt:** Fat-free milk, 1% milk, 2% milk, whole milk, flavored milk /flavored milk drinks, and yogurt; **Meat mixed dishes:** Mixed dishes from beef, pork, fish, chicken, turkey; **Salty Snacks/Crackers:** Salty crackers, popcorn, pretzels, corn chips, corn puffs, tortilla chips; **Milk-based Desserts/Sauces/Gravies:** Pudding, ice-cream, white sauce, milk-based gravy, milk-based dips, milk-based creamy dressing; **Grain mixtures (non-meat):** Rice/pasta dishes (e.g., rice soups, macaroni and cheese etc.), non-meat Mexican dishes, non-meat pizza; **Organ meats:** Organs from pork/beef/chicken/turkey (e.g., liver, tongue, chitterlings, gizzard, tripe).

CHAPTER V

THE ASSOCIATION BETWEEN BREAKFAST SKIPPING AND TYPE OF BREAKFAST CONSUMED WITH WEIGHT STATUS, METABOLIC SYNDROME, AND ITS RELATED RISK FACTORS IN YOUNG ADULTS: NHANES 1999-2006

(STUDY III)

Introduction

The prevalence of overweight/obesity among the United States (US) young adults, ages 20-39 years of age (y) is a public health concern, with 57.1% being overweight (body mass index [BMI) ≥ 25] and 28.5% being obese (BMI ≥ 30) (Ogden et al., 2006). The prevalence of metabolic syndrome (MetS), a constellation of metabolic risk factors for cardiovascular disease (CVD) and type 2 diabetes mellitus (T2DM), has increased in the US young adult population from 13.3% (in 1988-1994) to 18.0% (in 2003-2006) (Ervin, 2009; Ford et al., 2004). The presence of MetS in individuals increases the risk for CVD by two-fold and the risk for T2DM by five-fold (Grundy, 2008).

Young adulthood is a difficult period of transition from adolescence, with increasing responsibilities, having hurried lifestyles, and providing support for new families (Avery et al., 1992; Goldscheider & DaVanzo, 1989). This may translate into unhealthy dietary practices such as breakfast skipping (Deshmukh-Taskar, Radcliffe, Liu,

& Nicklas, submitted; Nicklas et al., 1998), eating fast foods (Pereira et al., 2005), or frequently eating meals outside the home (Clemens et al., 1999). Specifically, the habit of breakfast skipping is prevalent among the young adult population. Previous analyses on breakfast consumption using the 1999-2002 National Health and Nutrition Examination Survey (NHANES) showed that 25% of the young adults skipped breakfast (Deshmukh-Taskar et al., submitted). Skipping of breakfast has been associated with a higher than normal BMI in some cross-sectional (Cho et al., 2003; Kant, Andon, Angelopoulos, & Rippe, 2008; Song et al., 2005) and longitudinal studies (Van der Heijden et al., 2007) in adults. Conversely, consuming a breakfast that includes a ready-to-eat cereal (RTEC) has been associated with a lower BMI in comparison with those who skip breakfast (Cho et al.; Mattes, 2002; Song et al.) and with weight maintenance (Wyatt et al., 2002). Yet, very few US young adults (16.5%) consume RTEC at breakfast compared to those who consume other breakfast foods (OB) (58.4%) (Deshmukh-Taskar et al.).

Breakfast skipping or consumption patterns, especially, RTEC consumption may influence the food intake at subsequent meals during the day, by decreasing the energy density (Kant et al., 2008) and increasing the nutrient/diet quality of the meals (Deshmukh-Taskar et al., submitted). Ready-to-eat cereal breakfast consumers have been noted to have a lower intake of discretionary calories during the day and at breakfast (Deshmukh-Taskar et al.), and may consume smaller portion sizes at subsequent meals. However, no studies to date have examined whether breakfast skipping and type of breakfast consumed influences blood chemistries reflecting the occurrence of metabolic risk factors of MetS, CVD, and T2DM, especially among the young adult population.

The objective of this study was to examine the association of breakfast skipping and type of breakfast consumed (RTEC or OB) with the occurrence of overweight/obesity, abdominal obesity, and the overall occurrence of MetS and its related individual metabolic risk factors in young adults participating in the 1999-2006 NHANES.

Subjects and Methods

Study Design and Population

The NHANES was designed to provide health and nutrition information on participants representing the non-institutionalized US civilian population of all ages. Since 1999, the NHANES became a series of cross-sectional surveys spanning one year each. The survey used a multistage, stratified sampling design with over-sampling of individuals from certain ethnicities and age groups to ensure their adequate representation. The NHANES involved an in home-interview for demographic and basic health information, as well as a detailed health examination at the mobile examination center (MEC) conducted by highly trained examiners and interviewers of the survey. A detailed description of the NHANES procedures can be found elsewhere (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006; Lohman et al., 1988; Wright et al., 2007). All data collection procedures were subjected to quality control methods that included replicate measures, audiotaping of diet recalls, and periodic retraining sessions for the examiners.

For the present study, eight years of NHANES cross-sectional data, from 1999-2006, on young adults (20-39 y) were combined. Pregnant and or lactating subjects were excluded from the analyses. Data on only those with complete and reliable dietary recalls

(as indicated by the status code used in the dietary interview component to indicate the quality and completeness of the dietary recall) were included. Two datasets were analyzed, as depicted in Figure 9. The first dataset was analyzed for adiposity measures and individual metabolic risk factors for CVD, T2DM, and the MetS, that also included young adults who were fasting for those metabolic risk factors that required fasting values (as described later). The second dataset was analyzed for the overall occurrence of MetS and included only those young adults with data available on all five risk factors for the MetS (Grundy et al., 2006) as well as those who were fasting before blood draw. Due to the nature of the analysis (i.e., a secondary data analysis), and the lack of personal identifiers, this study was reviewed and approved in the exempt category by the Institutional Review Boards of Texas Woman's University, Houston, TX and Baylor College of Medicine, Houston, TX.

Dietary Assessment

The NHANES dietary interviewer recorded the type and amount of foods consumed by the sample persons via a single multi-pass 24-hour dietary recall using the computer-assisted dietary interview system that had standardized probes for eliciting the dietary information. The dietary recalls were conducted either in person or by telephone (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006; Wright et al., 2007). Although data from a non-consecutive second-day 24-hour dietary recall (i.e., a telephone interview conducted 3-10 days after the first dietary recall) were available in the NHANES since the year 2003, the present study used data from only the first day dietary recall to give equal weight to all

study years and to ensure consistency in the dietary methodology used. Breakfast consumption was self-reported and included consumption of any food/beverage at a meal reported by the participants as breakfast/brunch or desayuno/almuerzo (Spanish), together designated as 'breakfast' in this study. Subjects who consumed no foods/beverages at breakfast, excluding water, were categorized as breakfast skippers (BS). Ready-to-eat cereal breakfast consumers were defined as those who consumed RTEC at the breakfast meal occasion (regardless of other foods/beverages consumed at that meal occasion); and OB consumers were defined as those who consumed other foods/beverages excluding RTEC at the breakfast meal.

Anthropometric Measures

Trained examiners in the MEC conducted anthropometric measurements using calibrated instruments. Height was measured on a fixed stadiometer; weight was measured on a Toledo digital weight scale. Waist circumference (WC) was measured by placing a measuring tape at the highest point of the iliac crest to indicate the mid-axillary line of the body. Measurements for sub-scapular skinfold (obtained on the inferior angle of the right scapula) and triceps skinfold (obtained on the midpoint of the posterior side of right upper arm circumference) were made using the Holtain skinfold calipers (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006; Lohman et al., 1988). Body mass index (BMI) was assessed as weight (kg)/ height $(m)^2$.

Blood Pressure

The first and fifth phase korotkoff readings for systolic and diastolic blood pressure respectively were recorded using a calibrated mercury sphygmomanometer during the MEC examination (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). Three consecutive (and sometimes four) blood pressure readings were obtained on all eligible individuals; the present study used an average of first three blood pressure readings.

Laboratory Tests

The laboratory component procedures included automated collection, processing, storage, and shipment of biological specimens to analytical laboratories (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). Subsamples of individuals were used for plasma glucose, serum triglycerides, and serum low-density lipoprotein cholesterol (LDL-C), and appropriate sampling weights were used for those subsamples. In addition, only those individuals who were fasting at least for 9 hours for plasma glucose, serum insulin, serum triglycerides, and serum LDL-C were included (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey).

Total serum cholesterol, fasting serum triglycerides, and plasma glucose were measured spectrophotometrically using a series of enzymatic reactions (Roche Diagnostics, IN). Serum high-density lipoprotein cholesterol (HDL-C) was measured using enzymatic reactions by the heparin-manganese precipitation method and or a direct

immunoassay technique for limited serum sample volumes (Roche Diagnostics, IN). Serum LDL-C was calculated from measured fasting serum values of total cholesterol, triglycerides, and HDL-C according to the Friedewald calculation: [LDL-C]=[total cholesterol] – [HDL-C] – [triglycerides/5]. Fasting serum insulin was measured by immunoenzymometric assay (Tosoh Diagnostics, CA). Whole blood glycosylated hemoglobin was measured by an automated high-pressure liquid chromatography system (Primus I, model GLC 330, Primus Corp., MO); total serum homocysteine was measured by fluorescence immunoassay technique (Abbott Diagnostics, IL); serum C-reactive protein was measured by particle-enhanced immunoassay with latex enhanced nephelometry (Dade Behring Diagnostics Inc., NJ); and serum uric acid was measured enzymatically by a colorimetric method (Beckman Synchron LX20, Beckman Coulter Inc., CA) (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). Indices of insulin sensitivity and resistance were calculated according to the Quantitative Insulin Sensitivity Check Index (QUICKI) formula =1/ [log fasting plasma glucose (mg/dl) + log fasting plasma insulin (μU/ml)] (Katz et al., 2000) and the Homeostasis Model Assessment (HOMA) formula = [fasting plasma glucose (mg/dl) x fasting plasma insulin (μU/ml)] 405 (Matthews et al., 1985), respectively.

Definitions of Overweight Obesity and the Metabolic Syndrome (MetS)

Overweight/obesity was defined as BMI ≥ 25 (Centers for Disease Control and Prevention, 2000; National Institute of Health, 1998). Metabolic syndrome was defined

as having ≥ 3 of the following five risk factors: (1) abdominal obesity (WC ≥ 102 cm in males and ≥ 88 cm in females); (2) elevated serum triglycerides (≥150 mg/dL) or on drug treatment for elevated serum triglycerides; (3) reduced serum HDL-C (< 40 mg/dL in males or <50 mg/dL in females) or on drug treatment for reduced serum HDL-C; (4) elevated blood pressure (≥ 130 or ≥ 85 mm Hg or on drug treatment for elevated blood pressure/ hypertension); and (5) elevated fasting plasma glucose (≥100 mg/dl or on drug treatment for elevated glucose, [i.e., oral hypoglycemic agents/insulin]) (Grundy et al., 2006).

Covariates

Food group consumption tends to vary by socioeconomic, demographic, and lifestyle factors (Deshmukh-Taskar et al., 2007; Kourlaba et al., 2008; Yannakoulia et al., 2008). Therefore, demographic characteristics (i.e., age, gender, ethnicity, and ethnicity x gender, socioeconomic status (i.e., poverty income ratio [PIR]), marital status, and lifestyle habits (i.e., physical activity, smoking, and alcohol consumption) along with energy intake (kcal) were treated as covariates in the analyses. An assessment of multi-collinearity among the above covariates revealed low correlations ($r < \pm 0.4$, $p \leq 0.05$) between them. The data for all covariates (except energy and alcohol intake that were obtained from the dietary recall) were obtained from self-reported NHANES questionnaires. Ethnicity was defined as self-reported and categorized into non-Hispanic Whites, non-Hispanic Blacks, Mexican-Americans Hispanics and Other Mixed races. The PIR of the households was categorized into groups ranging from <1 (indicating

households below the poverty threshold) to ≥ 5. Physical activity was categorized into four groups, 'sedentary', 'light', 'moderate', and 'heavy'. Lifetime smoking status was defined as 'current', 'past', and 'never' smokers.

Statistical Analyses

Data analyses were conducted using Statistical Analysis Software ([SAS] 9.2, Cary, North Carolina, 2007) and SAS-callable Software for Analysis of Correlated Data (SUDAAN, 10.0, 2009) (Statistical Analysis Software, 2007; Software for the Analysis of Correlated Data, 2008). Details of statistical analytical procedures are described at the NHANES website (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 1999-2006). Eight-year sample weights and sub-sample weights were applied to the data to account for unequal probability of selection from over-sampling and for the stratified-multistage probability sample design (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey). Sample-weighted percents ± standard errors (SE) were obtained using PROC SURVEYFREQ. Chi-square test was used to determine differences among categorical variables. Pearson/Spearman correlations determined the multi-collinearity among the covariates. Sample-weighted least-squared means and least-squared standard errors were compared among three breakfast groups (i.e., BS, RTEC, and OB consumers) using covariate-adjusted analysis of variance (PROC REGRESS). Bonferroni's correction ($p<0.0167$) was used to adjust the significance level for multiple comparisons. Covariate-adjusted multinomial logistic regression was used to determine the association of breakfast skipping and type of breakfast consumed with overweight obesity, abdominal

obesity, MetS, and its related metabolic risk factors respectively. The traditional cut-off of $p \leq 0.05$ was used for (1) comparing categorical variables, and (2) for testing Pearson/Spearman correlations among the covariates. A significant association from the logistic regression model was defined if the unity was not in the 95% confidence interval (CI) of an odds ratio (OR).

Results

Demographic Characteristics

Twenty four percent of young adults were BS; 16.5% were RTEC consumers; and 59.7% were OB consumers (see Table 9). Among BS, a higher percent were males (58.0%) than females (42.0%). A lower percent of non-Hispanic Black, Mixed/Other race, and Mexican-American/Hispanic young adults (12.5%, 10.9%, and 12.7% respectively) appeared to be among RTEC consumers than non-Hispanic Whites (18.8%) *(data not shown)*. A higher percent of Mexican-Americans/Hispanics appeared to consume OB foods (67.9%) than non-Hispanic Whites (58%), non-Hispanic Blacks (55.7%) and those from Other/Mixed races (60.1%) *(data not shown)*. A higher percent of young adults who consumed RTEC at breakfast had a PIR ≥ 3 (24.7%) than having a PIR < 1 (13.8%). Being current smokers was higher in BS (30.4%) and OB consumers (55.8%) than in RTEC consumers (13.8%) *(data not shown)*. The amount of alcohol consumed was the lowest in RTEC consumers ($\bar{X}$ = 7.5 g day) and the highest in BS ($\bar{X}$ = 20.4 g/day) (see Table 9).

Covariate-adjusted Mean Individual Anthropometric and Metabolic Syndrome (MetS) Risk Factors by Type of Breakfast Consumption

Ready-to-eat cereal consumers had lower BMI and body fat measurements (i.e., triceps skinfold and sub-scapular skinfold) than BS and OB consumers; no difference in BMI was observed between BS and OB consumers (see Table 10). Waist circumference was the lowest among RTEC consumers, followed by OB consumers, and the highest in BS. Systolic blood pressure and serum levels of total cholesterol and insulin were lower for RTEC consumers than BS. Serum LDL-C was higher in the BS than in RTEC and OB consumers. Other breakfast food consumers had higher serum HDL-C than BS. Breakfast skippers had higher insulin resistance (as indicated by the higher mean value of HOMA) than RTEC consumers and had lower insulin sensitivity (as indicated by the lower mean value of QUICKI) than both the type of breakfast consumers. Blood glycosylated hemoglobin was lower in RTEC consumers than in BS and OB consumers. Serum homocysteine was lower in RTEC consumers than in BS and OB consumers (see Table 10).

Breakfast Skipping, Type of Breakfast Consumption, Weight Status, Metabolic Syndrome (MetS), and Metabolic Risk Factors

Among all young adults, 18.9% had MetS (≥ 3 of the five risk factors); 36% had abdominal obesity, 24.5% had elevated triglycerides, 20.5% had elevated blood pressure, 19.4% had impaired fasting glucose, and 35% had low HDL-C *(data not shown)*. The percent of young adults with metabolic risk factors by type of breakfast consumption is shown in Table 11. A lower percent of RTEC consumers had abdominal

consumers, and reduced serum HDL-C (in females) than BS. Further, a higher percent of BS and OB consumers were overweight/obese than RTEC consumers, in all young adults and both genders (see Table 11).

The association(s) between breakfast skipping/consumption and metabolic risk factors is depicted in table 12. Relative to RTEC consumers, BS and OB consumers had a 42% and a 27% higher odds of being overweight/obese (i.e., BMI $\geq$ 25) respectively. Relative to males who consumed RTEC, BS and OB consumers had a 85% and a 77% higher odds of having abdominal obesity (i.e., WC $\geq$ 102cm) respectively. Among females, BS had a 45% higher odds of having abdominal obesity (i.e., WC $\geq$ 88cm) relative to RTEC consumers. However, the association for abdominal obesity in females for OB vs. RTEC consumers and BS vs. OB consumers was not significant. Relative to RTEC consumers, BS had a 49% higher odds of having elevated systolic blood pressure, (i.e., $\geq$ 130 mmHg) and relative to OB consumers BS had a 37% higher odds of having elevated diastolic blood pressure (i.e., $\geq$ 85 mm Hg) (see Table 12).

Relative to RTEC consumers, BS had a 37% higher odds of having higher than the desirable levels for serum total cholesterol (i.e., > 200mg/dl) (National Cholesterol Education Program, 2001); whereas relative to OB consumers, BS had a 26% higher odds of having higher than desirable levels for serum total cholesterol (see Table 12). Relative to RTEC consumers, BS had a 82% higher odds of having elevated serum LDL-C (i.e., $\geq$130 mg/dl) (National Cholesterol Education Program); 17 times the odds of having elevated serum homocysteine (i.e., $\geq$ 16 µmol L) (Hyperhomocysteinemia, 2009), and a 71% higher odds of having elevated plasma insulin levels (i.e., > 20 µU ml)

(Quon, 2001). Relative to RTEC consumers, OB consumers had more than 6 times the odds of having elevated levels for serum homocysteine, and relative to OB consumers, BS had almost three times the odds of having elevated levels for serum homocysteine. Relative to OB consumers, BS had a 37% higher odds of having elevated serum LDL-C. Relative to males who consumed RTEC, those who skipped breakfast had a 53% higher odds of having reduced serum HDL-C (see Table 12).

Discussion

The present NHANES study from 1999-2006 is the first to examine the association between breakfast skipping and type of breakfast consumed with adiposity measures and risk factors for CVD, T2DM, and the occurrence of MetS, especially in the young adults. The occurrence of breakfast skipping and consumption in young adults observed in the present study is comparable to that reported in the earlier NHANES (Song et al., 2005). Demographic and lifestyle differences with respect to breakfast consumption revealed that a higher percent of RTEC breakfast consumers appeared to be among non-Hispanic Whites than the other ethnic groups, and in those who belonged to a higher socioeconomic stratum. Healthy food consumption is often influenced by demographic factors such as ethnicity, and socioeconomic status (reflecting ability to purchase and consume healthful foods), especially in younger populations (Clarke, O'Malley, Johnston, Schulenberg, & Lantz, 2009; Deshmukh-Taskar et al., 2007). Additionally, unhealthy dietary and lifestyle habits tend to co-exist among individuals. In the present study, it was interesting to note that a higher percent of BS appeared to be current smokers and consumed higher amounts of alcohol compared to RTEC consumers.

The mean BMI among all three breakfast groups in this study was ≥ 25. Yet, RTEC consumers had a lower odds of being overweight/obese relative to BS or OB consumers respectively. Previous studies have shown that skipping of breakfast and/or not eating RTEC at breakfast was associated with having a higher than normal BMI (Cho et al., 2003; Kant et al., 2008; Mattes, 2002; Song et al., 2005; Van der Heijden et al., 2007; Wyatt et al., 2002). Along with having a lower mean BMI, RTEC consumers had a lower odds of having abdominal obesity (i.e., had a lower WC) relative to BS or OB consumers respectively. Waist circumference, a surrogate measure of abdominal obesity, indicates the accumulation of both central subcutaneous and visceral fat. Recent studies have shown that compared to BMI, WC may help better to predict the risk for CVD (Zhu et al., 2005), T2DM (Wang et al., 2005), MetS (Han et al., 2002), medical care costs (Cornier et al., 2002), and all-cause mortality (Biggard et al., 2005). Although the mechanisms linking breakfast consumption with lower BMI/ body weight /WC are unclear, several theories may be suggested. While those who eat breakfast tend to consume a higher total daily energy intake than BS (Deshmukh-Taskar et al., submitted), BS may tend to eat more foods with a low nutrient density or diet quality (Deshmukh-Taskar et al., submitted; Nicklas et al., 1998) than breakfast consumers (especially, RTEC consumers). Compared to breakfast consumers, BS have also been noted to consume more of fast foods (Niemeier et al., 2006), and or a higher percent of energy from added sugars (Deshmukh-Taskar et al.) that may potentially contribute to weight gain. Conversely, eating breakfast may be associated with an increased eating frequency, which may in turn promote energy expenditure by increasing diet-induced thermogenesis

(Drummond et al., 1996). Regular breakfast consumption may also lead to more regular eating habits, a consistent energy intake, and selection of more healthful food choices, which may all contribute towards achieving lower BMI and body fat measures, and a smaller WC.

More specifically, consumption of RTEC at breakfast may help to lower adiposity measures. Ready-to-eat cereals are more nutrient-dense rather than energy-dense, since many RTEC (i.e., about 92% of those available) are fortified with vitamins and minerals and are low in fat; while some RTEC may also contribute to substantial amounts of dietary fiber (Anderson & Bridges, 1988; Ready-to-eat Cereals, 2008). The benefits of lowering fat intake and increasing dietary fiber are well-established, and are suggested as important strategies towards achieving a healthful diet (United States Department of Agriculture's Dietary Guidelines for Americans, 2005). Further, with RTEC consumption there is a higher intake of dairy foods (e.g., milk), which are excellent sources of many nutrients including protein and calcium. Higher calcium intake has been suggested to play a role in the regulation of body fat and body weight through the suppression of the lipogenesis promoting effects of calcitrol and intracellular Ca^{2+} that occur as a result of a lower calcium intake (Zemel et al., 2005). The increased intake of calcium with the consumption of RTEC (either attributed to the fortification of RTEC with calcium or to the typical addition of milk to RTEC [Song et al., 2006]) may thus help to lower body fat and BMI. Nevertheless, nutrition professionals should suggest caution while recommending RTEC, since many RTEC are presweetened, that may increase the intake of discretionary calories from added sugars in the diet (United States Department of

Agriculture's Dietary Guidelines for Americans). Added sugars if consumed in amounts >25% of the total energy intake (Institute of Medicine's Dietary Reference Intakes, 2006; United States Department of Agriculture's Dietary Guidelines for Americans) may contribute to weight gain and CVD (Bray et al., 2004; Duffey & Popkin, 2008; Johnson et al., 2009).

In tandem with the results on adiposity and weight status measures, the present study found that relative to RTEC consumers, BS had higher insulin resistance and lower insulin sensitivity, and had elevated serum levels of total cholesterol and LDL-C. The primary role of the hormone insulin is to promote glycogenesis and lipogenesis, and inhibit lipolysis (Eckel et al., 2005). However, insulin resistance may lead to increased amount of lipolysis of stored triglyceride molecules in the adipose tissue, leading to a higher production of circulating free fatty acids and other CVD-causing lipids (such as triglycerides, total cholesterol, and LDL-C) in the body (Eckel et al.). Further, insulin resistance may also lead to a higher accumulation of visceral/intra-abdominal fat (Eckel et al.). Owing to higher mean values for BMI, WC, and insulin resistance among BS than RTEC consumers in this study, higher serum mean values for CVD-causing lipids might have resulted in the BS. Further, skipping of breakfast may also cause a slow-down in the metabolic responses and energy expenditure that may in turn lead to metabolic shifts in insulin sensitivity and eventually leading to greater food consumption at other meals, more accumulation of body fat, and insulin resistance.

Previous NHANES breakfast analyses found that OB consumers had higher mean consumption of percent energy from fat (34%) and cholesterol (342 mg) than RTEC

consumers (30% and 258 mg respectively) and BS (31% and 242 mg respectively) during the day (Deshmukh-Taskar et al., submitted). A high-fat intake may raise serum levels of the cardio-protective HDL-C, but in turn may also raise other CVD-causing lipids such as serum triglycerides, total cholesterol, and LDL-C (Samaha, 2005), thereby negating the beneficial effects of raising serum HDL-C. In this study, the mean serum HDL-C level was higher in OB consumers than BS and may be attributed to a higher fat consumption among OB consumers than BS as observed earlier (Deshmukh-Taskar et al., submitted). Yet, the mean serum total cholesterol was higher in BS than RTEC consumers, but did not differ from OB consumers, and the mean serum LDL-C was higher in BS than in both RTEC and OB consumers. It is not clear whether dietary factors by themselves or in conjunction with hormonal shifts among those who skip breakfast may cause elevated levels of CVD-causing lipids in the body. In addition, the present results differ from some of the theories proposed by Samha (2005) regarding the role of high-fat intake in causing higher serum levels of CVD-causing lipids. This may be because younger adults (and not middle/older adults who are more prone to CVD) were examined in this research. Further investigation in this area is warranted.

Other breakfast consumers from the present study had higher mean blood glycosylated hemoglobin level (an indicator of long-term blood glucose control) than RTEC consumers, although the levels were within the normal reference range (< 5.9-7%) (Glycated hemoglobin, 2009). Yet, the mean values for glycosylated hemoglobin for the two breakfast groups were very close to each other, indicating that the differences among them may not be clinically significant, although being statistically significant. No

differences were found in mean serum levels of total cholesterol, triglycerides, LDL-C, mean levels for fasting plasma glucose and insulin, and the overall occurrence of MetS (i.e., presence of ≥ 3 of the five risk factors) among OB and RTEC consumers in the present study. Yet, a recent study (Devaraj et al., 2008) found that among middle-aged individuals with MetS, the consumption of a heart healthy low-fat breakfast, and a high-fat fast food style breakfast raised post-prandial (after two-hours) levels of serum glucose; however, the post-prandial levels of serum triglycerides and interleukin-1b increased only after the high-fat fast-food style breakfast meal and not after the heart healthy low-fat breakfast meal. The results from the above study suggested that high-fat breakfast consumption does contribute to higher post-prandial serum levels of CVD-promoting lipids and cytokines.

In the present study, relative to RTEC consumers, BS and OB consumers had significantly higher odds of having elevated serum homocysteine. These results may be attributed to the fortification of RTEC with B-vitamins especially, folate and vitamin B12. Homocysteine, a non-dietary amino acid in the body is synthesized from the demethylation of methionine and can be recycled to methionine or is converted to cysteine via multi-stage reactions, that involve the conversion of 5,10-methylenetetrahydrofolate to tetrahydrofolate (the biologically active form of folate). Vitamins B6 and B12 also act as cofactors in these reactions (Shils et al., 2005). Deficiencies of B vitamins including folate may thus lead to hyperhomocysteinemia. Hyperhomocysteinemia has been associated with endothelial dysfunction and is considered as a powerful risk factor for CVD (Moens et al., 2008). Yet, some studies

have found no beneficial effects of supplementing B-vitamins (especially, folate) on CVD risk (Song et al., 2009). Further, results from a recent meta-analysis (Khandanpour et al., 2009) indicate that not all studies suggest the positive relationship between hyperhomocysteinemia and CVD. Additional research to examine whether a relationship exists between lower serum homocysteine and reduced risk for CVD, particularly among RTEC consumers is warranted.

The present study did not find differences in C-reactive protein, (a marker of systemic inflammation) and serum uric acid (higher levels of which may lead to hyperglycemia by blocking the action of insulin) by breakfast skipping/consumption habits. Similar results to the present study for post-prandial levels of C-reactive protein were noted earlier, suggesting that C-reactive protein may not be directly influenced by dietary fat intake compared to other CVD risk factors such as serum triglycerides, total cholesterol, or LDL-C (Poppitt et al., 2008).

Limitations

Due to the cross-sectional nature of this study, causality between breakfast skipping or consumption, weight status, and metabolic risk factors cannot be explained (Willett, 1998). The use of a single, self-reported 24-hour dietary recall to assess breakfast consumption did not permit the assessment of the regular breakfast consumption habits of the population. Despite covering a large span of NHANES study years, the sample size for the assessment of the fasting values for metabolic risk factors was reduced largely from the original, due to missing data on several fasting variables. This may have lowered the power to detect differences among the breakfast groups in this

study. Despite the drawbacks, this study made an important novel contribution to the research on relationship between breakfast skipping and type of breakfast consumed with adiposity measures and some metabolic risk factors for CVD, T2DM, and the MetS.

Conclusions

The results from this study suggest several health benefits of breakfast consumption (especially, one that includes an RTEC). Efforts to lower prevalence of breakfast skipping in young adults are needed. Nutrition professionals should encourage the consumption of RTEC for breakfast in the young adult population. Future studies using multiple days of dietary assessment along with a longitudinal study design to determine the relationship between regular breakfast habits, weight status, and metabolic risk factors are suggested.

Table 9

Demographic Characteristics by Type of Breakfast Consumption in Young Adults (20-39 y): NHANES 1999-2006

Demographics	BS	RTEC consumers	OB consumers
Sample size (n)	1277	826	3213
Sample size** % ± SE	23.8 ± 0.7	16.5 ± 0.7	59.7 ± 0.9
Age (y)* Mean ± SE	28.1 ± 0.2[a]	29.6 ± 0.2[b]	30.4 ± 0.2[c]
Gender** % ± SE			
Males	58.0 ± 1.4	51.8 ± 2.1	51.2 ± 0.9
Females	42.0 ±1.4	48.2 ± 2.1	48.8 ± 0.9
Column p value	p<0.0001	NS	NS
Ethnicity*** % ± SE			
Non-Hispanic Whites	62.3 ± 2.4	73.4 ± 1.9	62.7 ± 1.7
Non-Hispanic Blacks	16.3 ± 1.4	9.3 ± 1.0	11.4 ± 1.0
Mexican-Americans/ Hispanics	14.6 ± 1.9	13.7 ± 1.3	20.4 ± 1.6
Other/Mixed races	6.8 ± 1.0	3.7 ± 0.8	5.6 ± 0.7
Column p value	p<0.0001	p<0.0001	p<0.0001

Table 9 continued

Demographics	BS	RTEC consumers	OB consumers
PIR** % ± SE			
< 1	18.6 ± 1.4	13.8 ± 1.5	15.6 ± 0.9
≥ 1 & < 2	25.8 ± 1.8	21.8 ± 1.9	22.1 ± 1.1
≥ 2 & < 3	18.3 ± 1.4	16.8 ± 2.0	16.9 ± 1.0
≥ 3 & < 5	24.3 ± 1.6	24.7 ± 1.9	26.4 ± 1.1
≥ 5	12.9 ± 1.6	22.9 ± 2.3	19.0 ± 1.1
Column p value	p<0.0001	p=0.001	p<0.0001
Smoking status*** % ± SE			
Never smokers	48.6 ± 2.0	62.7 ± 2.1	55.2 ± 1.2
Past smokers	10.8 ± 1.0	10.7 ± 1.1	15.1 ± 0.7
Current smokers	40.6 ± 1.9	26.7 ± 1.9	29.7 ± 1.1
Column p value	p<0.0001	p<0.0001	p<0.0001
Alcohol consumption g/day**[1] Mean ± SE	20.4 ± 2.4[a]	7.5 ± 1.0[b]	14.2 ± 0.9[a]

Table 9 continued

Demographics	BS	RTEC consumers	OB consumers
Physical activity % ± SE			
Sedentary	22.1 ± 1.2	22.3 ± 1.4	20.5 ± 0.9
Light	47.5 ± 1.7	49.2 ± 2.1	46.5 ± 0.9
Moderate	19.3 ± 1.3	19.2 ± 1.6	20.2 ±1.0
Heavy	11.1 ± 1.2	9.3 ±1.0	12.8 ± 0.8
Column p value	p<0.0001	p<0.0001	p<0.0001
Marital status* % ± SE**			
Never married	41.7 ± 1.9	33.9 ± 2.0	31.9 ± 1.4
Married/cohabiting	49.5 ± 1.7	58.6 ± 2.1	59.6 ± 1.4
Divorced/widowed/ separated	8.8 ± 1.0	7.5 ± 1.2	8.5 ± 0.6
Column p value	p<0.0001	p<0.0001	p<0.0001

Note. NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; PIR = poverty income ratio. Values are sample-weighted percents ± standard errors (SE) for categorical variables or sample-weighted least-squared means (LSM) ± least-squared standard errors (LSSE) for continuous variables. Column percents (as shown) add up to 100 and are indicated with the column p values from chi square test. Row percents for sample size, and all other demographic variables (*data not shown*) are also significant at p<0.0001 from chi square test. For continuous variables, means not sharing a same alphabetic character (a, b, c) within a row differ significantly (p<0.0167); BS vs. RTEC consumers, BS vs. OB consumers, RTEC consumers vs. OB consumers. Composite p values using the F test of ANOVA for demographic characteristics with significant multiple comparisons (a, b, c) within a row are ** p<0.0001, * p<0.05. For categorical variables, (i.e., percents), ***, ** indicate overall chi-square, significant at p<0.0001 and p=0.001 respectively. [1]Covariates: Energy intake, ethnicity, gender, gender x ethnicity, age, PIR, smoking status, physical activity, marital status.

Table 10

Individual Anthropometric and Metabolic Risk Factors by Type of Breakfast Consumption from a Reported 24-hour Dietary Recall in Young Adults (20-39 y): NHANES 1999-2006

Anthropometric risk factors	BS	RTEC consumers	OB consumers
		LSM ± LSSM	
Weight (kg)* (n=4752)**	81.6 ± 0.7[a]	77.3 ± 0.7[b]	80.1 ± 0.5[a]
BMI (kg/m^2)* (n=4746)**	28.0 ± 0.2[a]	26.6 ± 0.3[b]	27.4 ± 0.2[a]
WC (cm)* (n=4690)**	94.1 ± 0.5[a]	90.7 ± 0.6[b]	92.7± 0.4[c]
Triceps skinfold (mm)* (n=4309)	18.5 ± 0.3[a]	17.4 ± 0.3[b]	18.3 ± 0.2[a]
Sub-scapular skinfold (mm) (n=3832)**	19.1 ± 0.3[a]	17.5 ± 0.3[b]	18.7 ± 0.2[a]
Metabolic risk factors (serum/plasma/blood)			
Systolic blood pressure (mm Hg)* (n=4623)	115.4 ± 0.4[a]	113.9 ± 0.4[b]	115.0 ± 0.3[a, b]
Diastolic blood pressure (mm Hg) (n=4623)	70.6 ± 0.4	69.3 ± 0.5	69.9 ± 0.3

Table 10 continued

Metabolic risk factors (serum/plasma/blood)	BS	RTEC consumers	OB consumers
		LSM ± LSSM	
Total cholesterol (mg/dl)* (n=4537)	192.7 ± 1.6[a]	187.0 ±1.8[b]	188.8 ± 0.9[a, b]
Triglycerides(mg/dl)[1] (n=1986)	132.3 ± 5.5	128.2 ± 6.7	124.6 ± 3.7
LDL-C[1] (mg/dl)[1] ** (n=1947)	117.7 ± 1.9[a]	111.0 ± 2.6[b]	110.7 ± 1.0[b]
HDL-C[2] (mg/dl)** (n=4537)	50.0 ±0.4[a]	50.8 ± 0.4[a, b]	51.1 ± 0.3[b]
Glucose (mg/dl)[1] (n=1986)	95.6 ± 0.9	93.7 ± 0.8	94.8 ± 0.6
Insulin (μU/mL)[1] * (n=1977)	12.1 ± 0.7[a]	10.3 ± 0.4[b]	11.0 ± 0.4[a,b]
HOMA[1] * (n=1977)	3.0 ± 0.2[a]	2.5 ± 0.1[b]	2.6 ± 0.10 [a,b]
QUICKI[1] ** (n=1977)	0.1490 ±0.0009[a]	0.1529 ± 0.0011[b]	0.1517 ± 0.0005[b]

Table 10 continued

Metabolic risk factors (serum/plasma/blood)	BS	RTEC consumers	OB consumers
		LSM ± LSSM	
Glycosylated hemoglobin (%)** (n=4573)	5.3 ± 0.04[a]	5.1 ± 0.02[b]	5.2 ± 0.02[a]
Homocysteine (μmol/L)** (n=4573)	8.0 ± 0.1[a]	7.3 ± 0.1[b]	7.8 ± 0.1[a]
C-Reactive protein (mg/dl) (n=4554)	0.4 ± 0.02	0.4 ± 0.03	0.3 ± 0.01
Uric acid (mg/dl) (n = 4528)	5.4 ± 0.05	5.2 ± 0.04	5.3 ± 0.03

Note. NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; BMI = body mass index; WC = waist circumference; HDL = high-density lipoprotein cholesterol; LDL-C = low-density lipoprotein cholesterol; HOMA = homeostatic model assessment; QUICKI = quantitative insulin sensitivity check index. Values are sample-weighted least-squared means (LSSM) ± Least-squared standard errors (LSSE). [1]Fasting data and weights used. Covariates: Energy intake, age, gender, ethnicity, ethnicity x gender, smoking status, alcohol consumption, physical activity, marital status, and poverty income ratio (PIR). Means not sharing a same alphabetic character (a, b, c) within a row differ significantly ($p<0.0167$); BS vs. RTEC consumers, BS vs. OB consumers, RTEC consumers vs. OB consumers. Composite p values using the F test of ANOVA for metabolic risk factors with significant multiple comparisons (a, b, c) within each row are *** $p<0.0005$, ** $p< 0.005$, and * $p<0.05$.

Table 11

Percent of Young Adults (20-39 y) with Metabolic Risk Factors by Type of Breakfast Consumption from a Reported 24-hour Dietary Recall: NHANES 1999-2006

Metabolic risk factors	BS	RTEC consumers	OB consumers	Overall chi-square p value*
		% SE		
WC ≥ 102 cm (males)[1,2] *	27.3 ± 1.1	21.7 ± 1.2	29.9 ± 0.7	0.01
WC ≥ 88 cm (females)[1,2] *	50.1 ± 2.0	39.3 ± 2.7	46.2 ± 1.9	0.02
Systolic blood pressure ≥ 130 mm Hg[1,2] *	13.6 ± 1.2	8.6 ± 1.2	11.5 ± 0.6	0.005
Diastolic blood pressure ≥ 85 mm Hg[1,2]	10.2 ±1.2	8.7 ± 1.2	9.1 ± 0.6	0.5 (NS)
HDL-C < 40 mg/dl (males)[1,2]	31.6 ± 2.1	27.7 ± 2.3	29.4 ± 1.5	0.3 (NS)
HDL-C < 50 mg/dl (females)[1,2] *	46.1 ± 2.7	38.9 ± 2.5	36.1 ± 1.8	0.002
Triglycerides ≥ 150 mg/dl1[1,2]	25.2 ± 2.1	24.9 ± 2.4	23.4 ± 1.3	0.7 (NS)
Total cholesterol ≥ 200 mg/dl[2]	34.5 ± 1.5	29.4 ± 2.0	33.2 ± 0.9	0.1 (NS)

Table 11 continued

Metabolic risk factors	BS	RTEC consumers	OB consumers	Overall chi-square p value*
		% SE		
LDL-C ≥ 130mg/dl[2] *	30.3 ± 2.3	20.2 ± 2.7	26.3 ± 1.4	0.01
Glucose ≥ 100 mg/dl[1,2]	21.1 ± 2.3	16.4 ± 2.5	20.6 ± 1.1	0.3 (NS)
Insulin ≥ 20 µU/ml[2]	11.6 ± 1.7	9.1 ± 9.1	11.4 ± 0.8	0.5 (NS)
Glycosylated hemoglobin > 5.9% [2]	2.6 ± 0.6	1.5 ± 0.5	2.8 ± 0.4	0.1 (NS)
Homocysteine ≥ 16 µmol/L[2] *	1.9 ± 0.5	0.1 ± 0.1	0.8 ± 0.2	0.004
MetS (all)[2]	20.2 ± 2.4	17.0 ± 2.6	17.9 ± 1.5	0.6 (NS)
MetS (males)[2]	20.9 ± 3.1	21.6 ± 3.7	19.8 ± 2.1	0.9 (NS)
MetS (females)[2]	20.1 ± 2.6	13.7 ± 3.0	16.4 ± 1.8	0.3 (NS)
Overweight/obesity BMI ≥ 25 (all)[2] *	58.3 ± 1.5	51.7 ± 2.0	57.8 ± 1.2	0.02

Table 11 continued

Metabolic risk factors	BS	RTEC consumers	OB consumers	Overall chi-square p value*
		% SE		
Overweight/obesity BMI ≥ 25 (males)[2] *	58.6	56.0	63.5	0.02
Overweight/obesity BMI ≥ 25 (females)[2] *	57.8	47.1	51.8	0.03

Note. NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; BMI = body mass index; WC = waist circumference; HDL = high-density lipoprotein cholesterol; LDL-C = low-density lipoprotein cholesterol; HOMA = homeostatic model assessment; QUICKI = quantitative insulin sensitivity check index; MetS = metabolic syndrome; NS = not significant. Values are sample-weighted percents ± standard errors (SE) and indicate presence of a metabolic risk factor in young adults by breakfast groups. Percents across the three breakfast groups do not add to 100%. Sample size for each risk factor is shown Table10. Fasting weights and data used for serum triglycerides and LDL-C, and plasma glucose and insulin (including HOMA and QUICKI). * indicates overall chi-square p value. Individual categorical differences among breakfast groups depicted in table 12. [1]Risk factors included in the definition of MetS classified according to the revised Adult Treatment Panel (III) criteria.[2]Reference ranges for abnormal risk factors adapted from: **A)** Centers for Disease Control and Prevention (CDC). *Defining Overweight/Obesity* (2000, Updated, 2007). Retrieved February 17, 2009, from *http://www.cdc.gov/nccdphp/dnpa/obesity/defining.htm.* **B)** Glycated hemoglobin, (Updated 2009). Retrieved October 12, 2009, from *http://en.wikipedia.org/wiki/Glycated_hemoglobin.* **C)** Grundy, S.M., Cleeman, J.I., Daniels, S.R., Donato, K.A., Eckel, R.H., Franklin, B.A., et al. (2006). Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute scientific statement. *Current Opinion in Cardiology*, 21, 1-6. **D)** Hyperhomocysteinemia. *Coagulation Factors.* Retrieved October 12, 2009, from *http://www.coagulation-factors.com/articles/hypercoagulation%20disorders/hyperhomocysteinemia.php*. **E)** National Cholesterol Education Program (NCEP). Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). (2001). *The Journal of the American Medical Association*, 285, 2486–2497. **F)** Quon, M.J. (2001). Limitations of the fasting glucose to insulin ratio as an index of insulin sensitivity. J *Clin Endocrinol Metab*, 86, 4615-4617.

Table 12

Association of Breakfast Skipping and Type of Breakfast Consumption with Weight Status, MetS, and its Related Metabolic Risk Factors in Young Adults (20-39 y): NHANES 1999-2006

Abnormal metabolic risk factors (Present vs. Absent)	BS vs. RTEC (Referent)	OB vs. RTEC (Referent)	BS vs. OB (Referent)
		OR (CI)	
Abdominal obesity[1,3]			
WC ≥ 102 cm (males)	1.85 (1.31-2.6)*	1.77 (1.34-2.34)*	1.05 (0.8-1.34)
WC ≥ 88 cm (females)	1.45 (1.08-1.94)*	1.23 (0.91-1.66)	1.18 (0.93-1.50)
Overweight/obesity BMI ≥ 25[3]	1.42 (1.12 -1.80)*	1.27 (1.04-1.54)*	1.12 (0.95- 1.33)
MetS[1]	1.51(0.93-2.43)	1.11(0.73-1.68)	1.36 (0.92-2.02)
MetS[1] (males)	1.26 (0.66-2.41)	0.87(0.51-1.48)	1.45 (0.85-2.47)
MetS[1] (females)	1.79 (0.996-3.22)	1.48 (0.77-2.84)	1.21 (0.78-1.88)
Systolic blood pressure ≥ 130(mm Hg)[1,3]	1.49 (1.02-2.18)*	1.25 (0.91-1.71)	1.19 (0.95-1.50)

Table 12 continued

Abnormal metabolic risk factors (Present vs. Absent)	BS vs. RTEC (Referent)	OB vs. RTEC (Referent)	BS vs. OB (Referent)
		OR (CI)	
Diastolic blood pressure ≥ 85 (mm Hg)[1,3]	**1.38 (0.91-2.11)**	**1.01 (0.74-1.39)**	**1.37 (1.03-1.81)***
Triglycerides ≥ 150 (mg/dl)[1,2,3]	**1.15 (0.80-1.66)**	**0.91 (0.69-1.20)**	**1.26 (0.92-1.73)**
Total cholesterol > 200 (mg/dl)[3]	1.37 (1.06-1.76)*	1.09 (0.89-1.33)	1.26 (1.07-1.48)*
HDL-C [1,3]			
Males < 40 (mg/dl)[1,3]	1.53 (1.13-2.08)*	1.24 (0.93-1.66)	1.24 (0.9-1.54)
Females < 50 (mg/dl)[1,3]	1.097 (0.79-1.52)	0.86 (0.64-1.17)	1.27 (0.97-1.66)
LDL-C ≥ 130 (mg/dl)[2,3]	1.82(1.21-2.72)*	1.25(0.84-1.84)	1.37(1.06-1.79)*
Glucose ≥ 100 (mg/dl)[1,2,3]	1.30(0.79-2.15)	1.0(0.65-1.53)	1.31(1.0- 1.76)
Insulin > 20 (μU/mL)[2,3]	1.71 (1.01-2.89)*	1.39 (0.92-2.11)	1.22 (0.84-1.79)

Table 12 continued

Abnormal metabolic risk factors (Present vs. Absent)	BS vs. RTEC (Referent)	OB vs. RTEC (Referent)	BS vs. OB (Referent)
		OR (CI)	
Glycosylated hemoglobin > 5.9 (%)[3]	2.54 (0.98-6.60)	1.82 (0.79-4.19)	0.55 (0.24-1.26)
Homocysteine ≥ 16 (μmol/L)[3]	17.29 (3.54-84.39)*	6.44 (1.34-30.91)*	2.68 (1.14-6.34)*

Note. NHANES = National Health and Nutrition Examination Survey; BS = breakfast skippers; RTEC = ready-to-eat cereal; OB = other breakfast; BMI = body mass index; WC = waist circumference; HDL = high-density lipoprotein cholesterol; LDL-C = low-density lipoprotein cholesterol; MetS = metabolic syndrome. Values are Odds Ratios (OR) and Confidence Intervals (CI). * = statistically significant (i.e., unity not in the 95% CI of an OR). Sample size is shown Table 10. Covariates: Energy intake, age, gender, ethnicity, ethnicity x gender, smoking status, alcohol consumption, physical activity, marital status, poverty income ratio (PIR). [1]MetS classified according to the revised Adult Treatment Panel (III) Criteria. [2]Data for only those who were fasting before blood draw are used. [3]Reference ranges for abnormal risk factors adapted from: **A)** Centers for Disease Control and Prevention (CDC). *Defining Overweight/Obesity*. (2000, Updated, 2007). Retrieved February 17, 2009 from *http://www.cdc.gov/nccdphp/dnpa/obesity/defining.htm.* **B)** Glycated hemoglobin, (Updated 2009) .Retrieved October 12, 2009, from http://en.wikipedia.org/wiki/Glycated_hemoglobin. **C)** Grundy, S.M., Cleeman, J.I., Daniels, S.R., Donato, K.A., Eckel, R.H., Franklin, B.A., et al. (2006). Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute scientific statement. *Current Opinion in Cardiology*, 21, 1-6. **D)** Hyperhomocysteinemia. *Coagulation Factors.* Retrieved October 12, 2009, from http://www.coagulation-factors.com/articles/hypercoagulation%20disorders/hyperhomocysteinemia.php. **E)** National Cholesterol Education Program (NCEP). Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). (2001). *The Journal of the American Medical Association*, 285, 2486–2497. **F)** Quon, M.J. (2001). Limitations of the fasting glucose to insulin ratio as an index of insulin sensitivity. J *Clin Endocrinol Metab*, 86, 4615-4617.

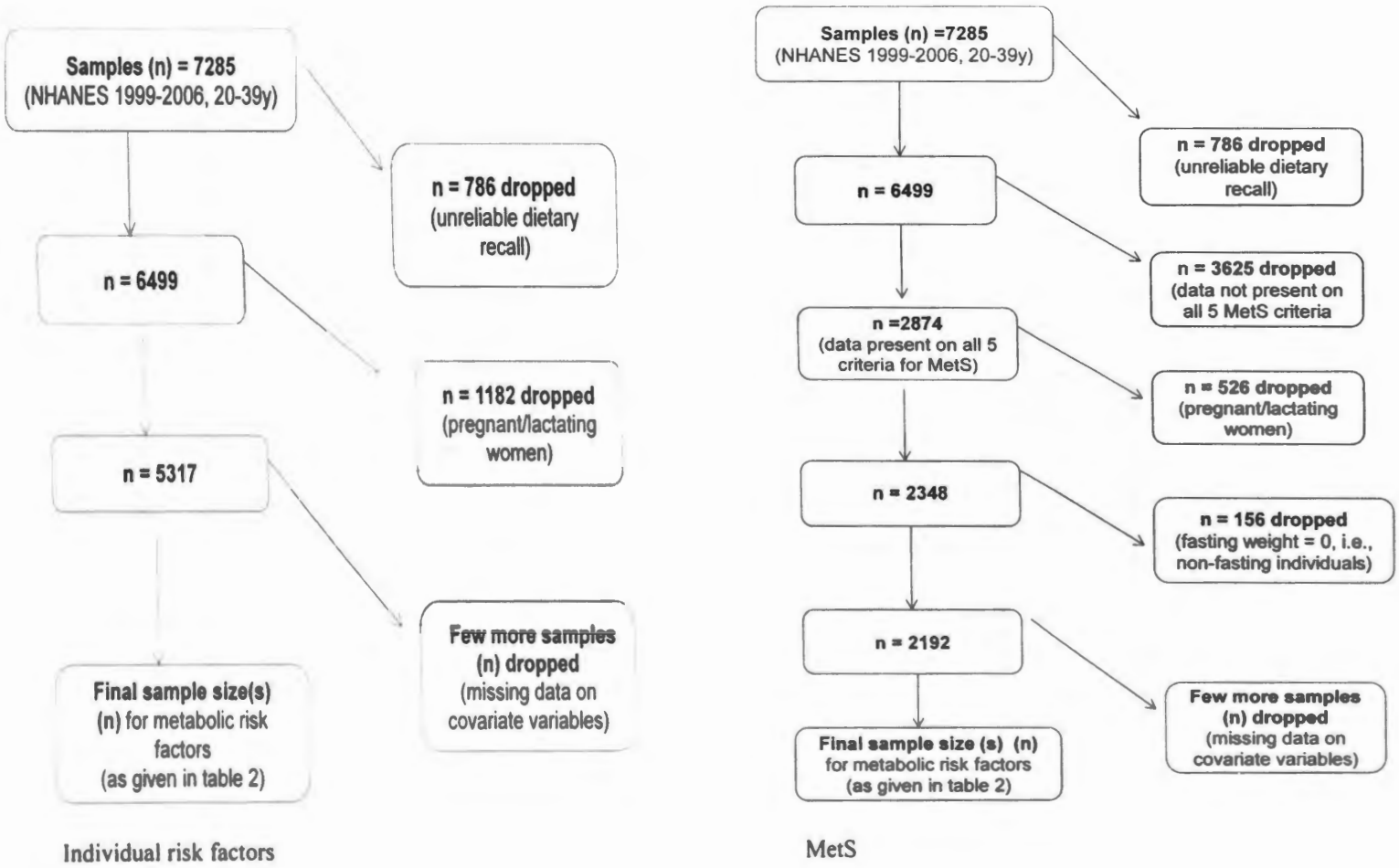

Figure 9. Sample size of young adults (20-39 y): NHANES 1999-2006. *Note.* NHANES = National Health and Nutritional Examination Survey; n = sample size; MetS = metabolic syndrome

CHAPTER VI

SUMMARY

The present research via three studies using the NHANES (1999-2006) highlighted the importance of breakfast consumption in improving nutrient intakes, nutrient adequacy, diet quality, adiposity measures, as well as metabolic risk factors among younger age groups (i.e., children [9-13 y] /adolescents [14-18 y] and young adults [20-39 y]). More specifically, percent of participants consuming RTEC at breakfast was lower among adolescents and young adults than in children, suggesting that healthy breakfast consumption habits tend to decline with age in younger populations. The null hypotheses were rejected for several aims in this dissertation. Concomitantly, among all age groups examined in the present dissertation, several macro- and micronutrient intakes (expressed as either mean percent energy or mean intakes) as well as the mean nutrient and diet adequacy scores were lower in BS and OB consumers than RTEC consumers. Fortified RTEC may be considered as healthful breakfast foods, due to their high nutrient density and low fat content. However, most fortified RTEC are also high in added sugars, since they are presweetened. Yet, participants who skipped breakfast had a higher consumption of added sugars per day compared to RTEC consumers among adolescents and young adults in the present studies.

In conjunction with having superior mean macro- and micronutrient intakes, RTEC consumers (in comparison to BS), had lower occurrence(s) of obesity (BMI $\geq$ 95th

percentile) in children/adolescents; overweight/obesity (BMI $\geq$ 25) in young adults; and abdominal obesity (i.e., a lower waist circumference) among all age groups studied. In addition, compared to OB consumers, RTEC consumers had lower occurrences of obesity/abdominal obesity in adolescents and overweight/obesity and abdominal obesity in young adults. Among young adults, relative to RTEC consumers, BS and OB consumers had higher odds of having of some individual metabolic risk factors (e.g., hyperhomocysteinemia), and BS had higher odds of having of hypercholesterolemia, higher serum LDL levels, and hyperinsulinemia. Thus consuming an RTEC at breakfast had both nutritional and health benefits among children/adolescents and young adults from a nationally representative sample of the US population.

CHAPTER VII

IMPLICATIONS AND RECOMMENDATIONS

Nutrition professionals should encourage the consumption of a healthy breakfast (especially one that includes an RTEC), among younger populations to improve their diet and to prevent the occurrence of abnormal metabolic risk factors. Yet, an impediment in the promotion and/or consumption of RTEC among individuals may be attributed to its higher cost in comparison to other easily accessible low-cost breakfast foods, such as eggs or meat products. Future research on breakfast consumption habits (especially, RTEC consumption) needs to examine its relationship with the cost factor, more so, in individuals from lower socioeconomic strata. In the present studies, some ethnic and socioeconomic differences in breakfast consumption habits were observed. For example, a higher percent of non-Hispanic Whites (especially young adults) and those from higher socioeconomic strata (in study III) appeared to be among RTEC breakfast consumers compared to the other US ethnic groups and those from lower-socioeconomic strata respectively. Further, some unhealthy lifestyle habits (such as smoking and alcohol consumption in young adults, or being sedentary in adolescents) appeared to be more prevalent among BS and OB consumers compared to RTEC consumers in the present studies. Therefore, future research should focus on examining the relationship of clustering of healthy breakfast habits (especially RTEC consumption) with socio-demographic characteristics (such as ethnicity and socioeconomic status) as

well as with healthy lifestyle habits (such as being a non-smoker, or consume lower amounts of alcohol, or being physically active).

Some limitations of the present studies included in this dissertation were their cross-sectional nature and the use of a single-day dietary recall to assess the regular breakfast consumption habits of the population. Therefore, future studies using longitudinal data and multiple days of dietary assessment to determine the relationship between regular breakfast habits, nutritional profiles, weight status, and metabolic risk factors are warranted. Concomitantly, the role of presweetened vs. non-sweetened RTEC in relation to weight status and metabolic risk factors needs to be examined.

REFERENCES

Affenito, S.G., Thompson, D.R., Barton, B.A., Franko, D.L., Daniels, S.R., Obarzanek, E., et al. (2005). Breakfast consumption by African-American and white adolescent girls correlates positively with calcium and fiber intake and negatively with body mass index. *Journal of the American Dietetic Association*, 105, 938-945.

Alberti, K.G.M.M., Zimmet, P., & Shaw, J. (2005). The metabolic syndrome - A new worldwide definition. *Lancet*, 366, 1059-1062.

Albertson, A.M., Anderson, G.H., Crockett, S.J., & Goebel, M.T. (2003). Ready-to-eat cereal consumption: its relationship with BMI and nutrient intake of children aged 4 to 12 years. *Journal of the American Dietetic Association*, 103, 1613-1619.

Anderson, J.W., & Bridges, S.R. (1988). Dietary fiber content of selected foods. *The American Journal of Clinical Nutrition*, 47, 440-447.

Assmann, G., Guerra, R., Fox, G., Cullen, P., Schulte, H., Willett, D., et al. (2007). Harmonizing the definition of the metabolic syndrome: Comparison of the criteria of the Adult Treatment Panel III and the International Diabetes Federation in United States American and European populations. *The American Journal of Cardiology*, 99, 541-548.

Avery, R., Goldscheider, F., & Speare, A. Jr. (1992). Feathered nest/gilded cage: parental income and leaving home in the transition to adulthood. *Demography*, 29, 375-388.

Bachman, J.L., Reedy, J., Subar, A.F., & Krebs-Smith, S.M. (2008). Sources of food group intakes among the US population, 2001-2002. *Journal of the American Dietetic Association*, 108, 804-814.

Backstrand, J.R. (2002). The history and future of food fortification in the United States: a public health perspective. *Nutrition Reviews*, 60, 15-26.

Banerjee, D., & Misra, A. (2007). Does using ethnic specific criteria improve the usefulness of the term metabolic syndrome? Controversies and suggestions. *The International Journal of Obesity (London)*, 3, 1340-1349.

Barton, B.A., Eldridge, A.L., Thompson, D., Affenito, S.G., Striegel-Moore, R.H., Franko, D.L., et al. (2005). The relationship of breakfast and cereal consumption to nutrient intake and body mass index: the National Heart, Lung, and Blood Institute Growth and Health Study. *Journal of the American Dietetic Association*, 105, 1383-1389.

Basiotis, P. P., Guenther, P. M., Lino, M., & Britten, P. (2006). Americans consume too many calories from solid fat, alcohol, and added sugar. U.S. Department of Agriculture (USDA) Center for Nutrition Policy and Promotion. *Nutrition Insight*, 33.

Berkey, C.S., Rockett, H.R., Gillman, M.W., Field, A.E., & Colditz, G.A. (2003). Longitudinal study of skipping breakfast and weight change in adolescents. *The International Journal of Obesity and Related Metabolic Disorders*, 27, 1258-1266.

Bigaard, J., Frederiksen, K., Tjønneland, A., Thomsen, B.L., Overvad, K., Heitmann, B.L., & Sørensen, T.I. (2005).Waist circumference and body composition in relation to all-cause mortality in middle-aged men and women. *The International Journal of Obesity (Lond)*, 29, 778-784.

Bowman, S.A., Friday, J.E., & Moshfegh, A. (2008). *My Pyramid Equivalents Database, 2.0 for USDA Survey Foods, 2003-2004*. Beltsville, MD: Food Surveys Research Group. Beltsville Human Nutrition Research Center, Agricultural Research Service, U.S. Department of Agriculture. Retrieved October 28, 2009, from http://www.ars.usda.gov/Services/docs.htm?docid=17563

Bray, G.A., Nielsen, S.J., & Popkin, B.M. (2004). Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity. *The American Journal of Clinical Nutrition*, 79, 537-543.

Breakfast Cereals. (2009). *Definition and Preparation*. Retrieved October 12, 2009, from http://www.answers.com/topic/cereal

Breakfast Research Institute. (2008). *Breakfast Basics*. Retrieved February 12, 2009, from http://www.breakfastresearchinstitute.org/breakfastbasics/whybreakfast/whyBreakfast.cfm

Britten, P., Marcoe, K., Yamini, S., & Davis, C. (2006). Development of food intake patterns for the MyPyramid Food Guidance System. *Journal of Nutrition Education and Behavior,* 38, S78-92.

Burger, K.S., Kern, M., & Coleman, K.J. (2007). Characteristics of self-selected portion size in young adults. *Journal of the American Dietetic Association,* 107, 611-618.

Centers for Disease Control and Prevention.

Defining Overweight/Obesity. (2000, Updated, 2007). Retrieved February 17, 2009, from http://www.cdc.gov/nccdphp/dnpa/obesity/defining.htm

Growth Charts. (2000). Retrieved February 13, 2009, from http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/background.htm

A Statistical Analysis Software Program for the Growth Charts. (2007). Hyattsville, MD: US Department of Health and Human Services. Retrieved October 28, 2009, from http://www.cdc.gov/nccdphp/dnpa/growthcharts/resources/sas.htm

Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey. (2001-2002). *Breakfast in America.* What We Eat in America. Retrieved February 12, 2009, from *http://www.ars.usda.gov/SP2UserFiles/Place/12355000/pdf/Breakfast_2001_2002.pdf*

Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey. (1999-2006). National Center for Health Statistics. *Overview.* Retrieved January 16, 2009, from *http://www.cdc.gov/nchs/nhanes/about_nhanes.htm*

http://www.cdc.gov/nchs/data/nhanes/nhanes_07_08_overviewbrochure_0708.pdf

Survey Operations Manuals, Brochures, & Consents. Retrieved January 16, 2009, from *http://www.cdc.gov/nchs/about/major/nhanes/nhanes99_00.htm*

http://www.cdc.gov/nchs/about/major/nhanes/nhanes01-02.htm

http://www.cdc.gov/nchs/nhanes/nhanes20032004/nhanes03_04.htm

http://www.cdc.gov/nchs/nhanes/nhanes2005-2006/nhanes05_06.htm

Anthropometry Manual. Retrieved January 16, 2009, from *http://www.cdc.gov/nchs/data/nhanes/bm.pdf*

NHANES Anthropometric Procedures Video. Retrieved January 16, 2009, from *http://www.cdc.gov/nchs/products/elec_prods/subject/video.htm*

Dietary Recall Status and Dietary Interviewers Manual. Retrieved January 16, 2009, from *http://www.cdc.gov/nchs/data/nhanes/dr-1-5.pdf.*

http://www.cdc.gov/nchs/tutorials/Dietary/AdditionalResources/Info_DietaryVariables.htm

http://www.cdc.gov/nchs/data/nhanes/nhanes_05_06/dr1tot_d.pdf

Laboratory Methods. Retrieved January 16, 2009, from *http://www.cdc.gov/nchs/nhanes/nhanes2005-2006/lab_methods_05_06.htm*

http://www.cdc.gov/nchs/about/major/nhanes/nhanes2003-2004/lab_methods_03_04.htm

Physician Examination Procedures Manual. Retrieved January 16, 2009, from *http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/PE.pdf*

Analytical Guidelines. Retrieved July 21, 2007, from *http://www.cdc.gov/nchs/about/major/nhanes/nhanes2003-2004/analytical_guidelines.htm*

http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/nhanes_analytic_guidelines_dec_2005.pdf

Sample Weighting. Retrieved January 16, 2009, from *http://www.cdc.gov/nchs/tutorials/NHANES/SurveyDesign/Weighting/intro.htm.*

http://www.cdc.gov/nchs/nhanes/nhanes2005-2006/faqs05_06.htm.

Subsample Notes and Data. Retrieved January 16, 2009, from *http://www.cdc.gov/nchs/data/nhanes/nhanes_subsample_notes.pdf*

Centers for Disease control and Prevention. (1999-2002). *Prevalence of Overweight Among Children and Adolescents: United States*. National Center for Health Statistics. Retrieved November 14, 2009, from *http://www.cdc.gov/nchs/data/hestat/overweight/overwght_child_03.htm*.

Cho, S., Dietrich, M., Brown, C.J., Clark, C.A., & Block, G. (2003). The effect of breakfast type on total daily energy intake and body mass index: results from the Third National Health and Nutrition Examination Survey (NHANES III). *Journal of the American College of Nutrition*, 22, 296-302.

Clarke, P.J., O'Malley, P.M., Johnston, L.D., Schulenberg, J.E., & Lantz, P. (2009) Differential trends in weight-related health behaviors among American young adults by gender, race/ethnicity, and socioeconomic status: 1984-2006. *The American Journal of Public Health*, 99, 1893-1901.

Clemens, L.H., Slawson, D.L., & Klesges, R.C. (1999). The effect of eating out on quality of diet in premenopausal women. *Journal of the American Dietetic Association*, 99, 442-444.

Cohn, G.S., Kittleson, M.M., & Blumenthal, R.S. (2005). Toward an improved diagnosis of the metabolic syndrome other clues to the presence of insulin resistance. *The American Journal of Hypertension*, 18, 1099-1103.

Condon, E.M., Crepinsek, M.K., & Fox, M.K. (2009). School meals: types of foods offered to and consumed by children at lunch and breakfast. *Journal of the American Dietetic Association*, 109, 67S-78S.

Cornier, M.A., Tate, C.W., Grunwald, G.K., & Bessesen, D.H. (2002). Relationship between waist circumference, body mass index, and medical care costs. *Obesity Research,* 10, 1167–1172.

Cotton, P.A., Subar, A.F., Friday, J.E., & Cook, A. (2004). Dietary sources of nutrients among US adults, 1994 to 1996. *Journal of the American Dietetic Association,* 104, 921-930.

Davy, B.M., Harrell, K., Stewart, J., & King, D.S. (2004). Body weight status, dietary habits, and physical activity levels of middle school-aged children in rural Mississippi. *South Medical Journal,* 97, 571-577.

Deshmukh-Taskar, P., Nicklas T.A., Morales M., Yang S.J., Zakeri I., & Berenson G.S. (2006). Tracking of overweight status from childhood to young adulthood: the Bogalusa Heart Study. *The European Journal of Clinical Nutrition,* 60, 48-57.

Deshmukh-Taskar, P., Nicklas, T.A., Yang, S.J., & Berenson, G.S. (2007). Does food group consumption vary by differences in socioeconomic, demographic, and lifestyle factors in young adults? The Bogalusa Heart Study. *Journal of the American Dietetic Association,* 107, 223-234.

Deshmukh-Taskar, P.R., Radcliffe, J.D., Liu, Y., & Nicklas, T.A. Does breakfast skipping and breakfast type affect energy intake, nutrient intake, nutrient adequacy, and diet quality in young adults? NHANES 1999-2002. *Journal of the American College of Nutrition.* Submitted.

Devaraj, S., Wang-Polagruto, J., Polagruto, J., Keen, C.L., & Jialal, I. (2008). High-fat, energy-dense, fast-food-style breakfast results in an increase in oxidative stress in metabolic syndrome. *Metabolism*, 57, 867-870.

Drummond, S., Crombie, N., & Kirk, T. (1996). A critique of the effects of snacking on body weight status. *The European Journal of Clinical Nutrition,* 50, 779 –783.

Duffey, K.J., Gordon-Larsen, P., Jacobs, D.R. Jr., Williams, O.D., & Popkin, B.M. (2007). Differential associations of fast food and restaurant food consumption with 3-y change in body mass index: the CARDIA Study. *The American Journal of Clinical Nutrition*, 85, 201-208.

Duffey, K.J., & Popkin, B.M. (2008). High-fructose corn syrup: is this what's for dinner? *The American Journal Clinical Nutrition.* 88, 1722S-1732S.

Eckel, R.H., Grundy, S.M., & Zimmet, P.Z. (2005). The metabolic syndrome. *Lancet.* 365, 1415-1428.

Ervin, R.B. (2009). Prevalence of metabolic syndrome among adults 20 years of age and over, by sex, age, race and ethnicity, and body mass index: United States, 2003–2006. *National Health Statistics Reports*: no 13. Hyattsville, MD: National Center for Health Statistics.

Ferris, M., Hogan, S.L., Chin, H., Shoham, D.A., Gipson, D.S., Gibson, K., et al. (2007). Obesity, albuminuria, and urinalysis findings in US young adults from the Add Health Wave III study. *Clinical Journal of the American Society of Nephrology*, 2, 1207-1214.

Finkelstein, E.A., Fiebelkorn, I.C., & Wang, G. (2004). State-level estimates of annual medical expenditures attributable to obesity. *Obesity Research,* 12, 18-24.

Flegal, K.M., Carroll, M.D., Kuczmarski, R.J., & Johnson, C.L. (1998). Overweight and obesity in the United States: prevalence and trends, 1960-1994. *The International Journal of Obesity & Related Metabolic Disorders,* 22, 39-47.

Food Research and Action Center. (2005). *School Breakfast Scorecard.* Washington, DC. Retrieved October 28, 2009, from *http://www.frac.org/pdf/2005_SBP.pdf*

Ford, E.S., Giles, W.H., & Mokdad, A.H. (2004). Increasing prevalence of the metabolic syndrome among US Adults. *Diabetes Care,* 27, 2444-2449.

Frary, C.D., Johnson, R.K., & Wang, M.Q. (2004). Children and adolescents' choices of foods and beverages high in added sugars are associated with intakes of key nutrients and food groups. *Journal of Adolescent Health,* 34, 56-63.

Friday, J.E., & Bowman, S.A. (2006). *My Pyramid Equivalents Database for USDA Survey Food Codes, 1994-2002.* Version 1.0. U.S. Department of Agriculture, Agriculture Research Service. Retrieved October 28, 2009, from *http://www.ba.ars.usda.gov/cnrg*

Gibson, S. (2003). Micronutrient intakes, micronutrient status and lipid profiles among young people consuming different amounts of breakfast cereals: further analysis of data from the National Diet and Nutrition Survey of Young People aged 4 to 18 years. *Public Health Nutrition,* 6, 815-820.

Gidding, S.S., Dennison, B.A., Birch, L.L., Daniels, S.R., Gillman, M.W., Lichtenstein, A.H., Rattay, K.T., Steinberger, J., Stettler, N., & Van Horn, L. (2006). American Heart Association. Dietary recommendations for children and adolescents: a guide for practitioners. *Pediatrics,* 117, 544-559.

Glycated hemoglobin. (Updated 2009). Retrieved October 12, 2009, from *http://en.wikipedia.org/wiki/Glycated_hemoglobin*

Goldscheider, F.K., & DaVanzo, J. (1989). Pathways to independent living in early adulthood: marriage, semiautonomy, and premarital residential independence. *Demography,* 26, 597-614.

Goodman, E., Adler, N.E., Daniels, S.R., Morrison, J.A., Slap, G.B., & Dolan, L.M. (2003). Impact of objective and subjective social status on obesity in a biracial cohort of adolescents. *Obesity Research,* 11, 1018-1026.

Goran, M.I., Driscoll, P., Johnson, R., Nagy, T.R., & Hunter, G. (1996). Cross-calibration of body-composition techniques against dual-energy X-ray absorptiometry in young children. *The American Journal of Clinical Nutrition,* 63, 299-305.

Grundy, S.M. (2008). Metabolic Syndrome Pandemic. *Arteriosclerosis Thrombosis and Vascular Biology.* (Abstract).

Grundy, S.M., Cleeman, J.I., Daniels, S.R., Donato, K.A., Eckel, R.H., Franklin, B.A., et al. (2006). Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute scientific statement. *Current Opinion in Cardiology,* 21, 1-6.

Guenther, P.M., Reedy, J., Krebs-Smith, S.M., Reeve, B.B., & Basiotis, P.P. (2007). Development and evaluation of the Healthy Eating Index-2005: Technical report. *Center for Nutrition Policy and Promotion*, US Department of Agriculture (USDA).

Guthrie, J.F., & Morton, J.F. (2000). Food sources of added sweeteners in the diets of Americans. *Journal of the American Dietetic Association*, 100, 43-51.

Han, T.S., Williams, K., Sattar, N., Hunt, K.J., Lean, M.E., & Haffner, S.M. (2002). Analysis of obesity and hyperinsulinemia in the development of metabolic syndrome: San Antonio Heart High Cholesterol in Adults. *Obesity Research*, 10, 923-931.

Hession, M., Rolland, C., Kulkarni, U., Wise, A., & Broom, J. (2009). Systematic review of randomized controlled trials of low-carbohydrate vs. low-fat/low-calorie diets in the management of obesity and its co-morbidities. *Obesity Reviews*, 10, 36-50.

Hyperhomocysteinemia. *Coagulation Factors*. Retrieved October 12, 2009, from http://www.coagulation-factors.com/articles/hypercoagulation-disorders/hyperhomocysteinemia.php

Ingwersen, J., Defeyter, M.A., Kennedy, D.O., Wesnes, K.A., & Scholey, A.B. (2007). A low glycemic index breakfast cereal preferentially prevents children's cognitive performance from declining throughout the morning. *Appetite*, 49, 240-244.

Institute of Medicine. *Dietary Reference Intakes*. (2006). The Essential guide to nutrient requirements. The National Academic Press, Washington.

Insulin. (Updated, 2009). *Wikipedia.* Wikimedia Foundation, Inc., Retrieved October 26, 2009, from http://en.wikipedia.org/wiki/Insulin

International Diabetes Federation. (2005). *A new worldwide definition of the metabolic syndrome consensus from the International Diabetes Federation could help stop the cardiovascular disease time bomb.* Retrieved October 26, 2009, from http://www.idf.org/webdata/docs/MetS_def_update2006.pdf

Johnson, M.A., Smith, M.M., & Edmonds, J.T. (1998). Copper, iron, zinc, and manganese in dietary supplements, infant formulas, and ready-to-eat breakfast cereals. *The American Journal of Clinical Nutrition*, 67, 1035S-1040S.

Johnson, R.K., Appel, L.J., Brands, M., Howard, B.V., Lefevre, M., Lustig, R.H. et al. (2009). Dietary sugars intake and cardiovascular health: a scientific statement from the American Heart Association. *Circulation*, 120, 1011-1020.

Kafatos, A., Linardakis, M., Bertsias, G., Mammas, I., Fletcher, R., & Bervanaki, F. (2005). Consumption of ready-to-eat cereals in relation to health and diet indicators among school adolescents in Crete, Greece. *Annals of Nutrition and Metabolism*, 49, 165-172.

Kahn, B.B. & Flier, J.S. (2000). Obesity and insulin resistance. *The Journal of Clinical Investigation*, 106, 473-481.

Kant, A.K. (1996). Indexes of overall diet quality: a review. *Journal of the American Dietetic Association*, 96, 785-791.

Kant, A.K., Andon, M.B., Angelopoulos, T.J., & Rippe, J.M. (2008). Association of breakfast energy density with diet quality and body mass index in American adults: National Health and Nutrition Examination Surveys, 1999-2004. *The American Journal of Clinical Nutrition,* 88, 1396 -1404.

Katz, A., Nambi, S.S., Mather, K., Baron, A.D., Follmann, D.A., Sullivan, G., & Quon, M.J. (2000). Quantitative insulin sensitivity check index: a simple, accurate method for assessing insulin sensitivity in humans. *Journal of Clinical Endocrinology and Metabolism*, 85, 2402–2410.

Kennedy, E., & Davis, C. (1998). US Department of Agriculture, School Breakfast Program. *The American Journal of Clinical Nutrition*, 67, 798S-803.

Khandanpour, N., Loke, Y.K., Meyer, F.J., Jennings, B., & Armon, M.P. (2009). Homocysteine and peripheral arterial disease: systematic review and meta-analysis. *European Journal of Vascular and Endovascular Surgery*, 38, 316- 322.

Kim, Y.B., Shulman, G.I., & Kahn, B.B. (2002). Fatty acid infusion selectively impairs insulin action on Akt1 and protein kinase C lambd zeta but not on glycogen synthase kinase-3. *Journal of Biological Chemistry*, 277, 32915-32922.

Kipke, M.D., Iverson, E., Moore, D., Booker, C., Ruelas, V., Peters, A.L., & Kaufman, F. (2007). Food and park environments : neighborhood-level risks for childhood obesity in east Los Angeles. *Journal of Adolescent Health*, 40, 325-333.

Kirwan, J.P., O'Gorman, D., & Evans, W. J. (1998). A moderate glycemic meal before endurance exercise can enhance performance. *Journal of Applied Physiology*, 84, 53-59.

Klein, S. (2004). Clinical trial experience with fat-restricted vs. carbohydrate-restricted weight-loss diets. *Obesity Research,* 12, 141S-144S.

Kourlaba, G., Panagiotakos, D.B., Mihas, K., Alevizos, A., Marayiannis, K., Mariolis, A., & Tountas, Y. (2008). Dietary patterns in relation to socio-economic and lifestyle characteristics among Greek adolescents: a multivariate analysis. *Public Health Nutrition,* 9, 1-7.

Krebs-Smith, S.M., & Clark, L.D. (1989). Validation of a nutrient adequacy score for use with women and children. *Journal of the American Dietetic Association*, 89, 775-783.

Lada, A.T., & Rudel, L.L. (2004). Associations of low-density lipoprotein particle composition with atherogenicity. *Current Opinion in Lipidology*, 15, 19-24.

Lake, A.A., Mathers, J.C., Rugg-Gunn, A.J., & Adamson, A.J. (2006). Longitudinal change in food habits between adolescence (11-12 years) and adulthood (32-33 years): the ASH30 Study. *Journal of Public Health (Oxford)*, 28, 10-16.

Li, C., Ford, E.S., McGuire, L.C., & Mokdad, A.H. (2007). Increasing trends in waist circumference and abdominal obesity among US adults. *Obesity (Silver Spring)*, 15, 216-224.

Li, C., Ford, E.S., Mokdad, A.H., & Cook, S. (2006). Recent trends in waist circumference and waist-height ratio among US children and adolescents. *Pediatrics*, 118, e1390-1398.

Lioret, S., Volatier, J.L., Lafay, L., Touvier, M., & Maire, B. (2009). Is food portion size a risk factor of childhood overweight? *The European Journal of Clinical Nutrition*, 63, 382-391.

Lohman, T.G., Roche, A.F., & Martorell, R. (1988). Anthropometric standardization reference manual. Human kinetics books, Champaign, IL, Abridged ed. cited in Wright JD, Borrud , L.G., McDowell, M.A., Wang, C.Y., Radimer, K., & Johnson, C.L. (2007). Nutrition assessment in the National Health and Nutrition Examination Survey 1999-2002. *Journal of American Dietetic Association*, 107, 822-829.

Lorenzo, C., Serrano-Rios, M., Martinez-Larrad, M.T., Gonzalez-Sanchez, J.L., Seclen, S., Villena, A., et al. (2006). Geographic variations of the International Diabetes Federation and the National Cholesterol Education Program-Adult Treatment Panel III definitions of the metabolic syndrome in non-diabetic subjects. *Diabetes Care*, 29, 685- 691.

Madden, J.P., Goodman, S.J., & Guthrie, H.A. (1976). Validity of the 24-hr. recall. Analysis of data obtained from elderly subjects. *Journal of the American Dietetic Association*, 68, 143-147.

Malinauskas, B.M., Raedeke, T.D., Aeby, V.G., Smith, J.L., & Dallas, M.B. (2006). Dieting practices, weight perceptions, and body composition: a comparison of normal weight, overweight, and obese college females. *Nutrition Journal*, 5, 11.

Mattes, R.D. (2002). Ready-to-eat cereal used as a meal replacement promotes weight loss in humans. *Journal of the American College of Nutrition*, 21, 570-577.

Matthews, D.R., Hosker, J.P., Rudenski, A.S., Naylor, B.A., Treacher, D.F., & Turner, R.C. (1985). Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia*, 28, 412–419.

McCabe-Sellers, B.J., Bowman, S., Stuff, J.E., Champagne, C.M., Simpson, P.M., & Bogle, M.L. (2007). Assessment of the diet quality of US adults in the Lower Mississippi Delta. *The American Journal of Clinical Nutrition*, 86, 697-706.

Miech, R.A., Kumanyika, S.K., Stettler, N., Link, B.G., Phelan, J.C., & Chang, V.W. (2006). Trends in the association of poverty with overweight among US adolescents, 1971-2004. *The Journal of the American Medical Association*, 295, 2385-2393.

Misra, M., Tsai, P.M., Mendes, N., Miller, K.K., & Klibanski, A. (2009). Increased carbohydrate induced ghrelin secretion in obese vs. normal-weight adolescent girls. *Obesity (Silver Spring)*, 17, 1689-1695.

Moens, A.L., Vrints, C.J., Claeys, M.J., Timmermans, J.P., Champion, H.C., & Kass, D.A. (2008). Mechanisms and potential therapeutic targets for folic acid in cardiovascular disease. *Am J Physiol Heart Circ Physiol*, 294, H1971-7.

Morland, K., & Filomena, S. (2007). Disparities in the availability of fruits and vegetables between racially segregated urban neighborhoods. *Public Health Nutrition*, 10, 1481-1489.

Moshfegh, A., Goldman, J., & Cleveland, L. (2005). What We Eat in America, NHANES 2001-2002: Usual nutrient intakes from food compared to Dietary Reference Intakes. *Agricultural Research Service / U.S. Department of Agriculture* (Ed.).

National Cholesterol Education Program. (2001). Expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). *The Journal of the American Medical Association*, 285, 2486–2497.

National Heart, Blood and Lung Institute. (2007). *Diseases and Conditions Index: Metabolic syndrome*. US Department of Health and Human Services. National Institute of Health. Retrieved January 16, 2009, from *http://www.nhlbi.nih.gov/health/dci/Diseases/ms/ms_whatis.html*

National Institutes of Health. (1998). Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults – the evidence report. *Obesity Research*, 6, 51S - 209S.

Nicklas, T.A., Myers, L., Reger, C., Beech, B., & Berenson, G.S. (1998). Impact of breakfast consumption on nutritional adequacy of the diets of young adults in Bogalusa, Louisiana: ethnic and gender contrasts. *Journal of the American Dietetic Association*. 98. 1432-1438.

Nicklas, T.A., O'Neil, C., & Myers, L. (2004). The importance of breakfast consumption to nutrition of children, adolescents, and young adults. *Nutrition Today*. 39, 30-39.

Nicklas, T.A. , Reger, C., Myers, L., & O'Neil, C. (2000). Breakfast consumption with and without vitamin-mineral supplement use favorably impacts daily nutrient intake of ninth-grade students. *Journal of Adolescent Health*, 27, 314-321.

Niemeier, H.M., Raynor, H.A., Lloyd-Richardson, E.E., Rogers, M.L., & Wing, R.R. (2006). Fast food consumption and breakfast skipping: predictors of weight gain from adolescence to adulthood in a nationally representative sample. *Journal of Adolescent Health*, 39, 842-849.

Ogden, C.L., Carroll, M.D., Curtin, L.R., McDowell, M.A., Tabak, C.J., & Flegal, K.M. (2006). Prevalence of overweight and obesity in the United States, 1999-2004. *Journal of the American Medical Association*, 295, 1549-1555.

Pereira, M.A., Jacobs, D.R. Jr., Van Horn, L., Slattery, M.L., Kartashov, A.I., & Ludwig, D.S. (2002). Dairy consumption, obesity, and the insulin resistance syndrome in young adults: the CARDIA Study. *Journal of the American Medical Association*, 287, 2081-2089.

Pereira, M.A., Kartashov, A.I., Ebbeling, C.B., Van Horn, L., Slattery, M.L., Jacobs, D.R. Jr., & Ludwig, D.S. (2005). Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet*, 365, 36-42.

Poppitt, S.D., Keogh, G.F., Lithander, F.E., Wang, Y., Mulvey, T.B., Chan, Y.K., McArdle, B.H., & Cooper, G.J. (2008). Postprandial response of adiponectin, interleukin-6, tumor necrosis factor-alpha, and C-reactive protein to a high-fat dietary load. *Nutrition*, 24, 322-329.

Quon, M.J. (2001). Limitations of the fasting glucose to insulin ratio as an index of insulin sensitivity. J *Clin Endocrinol Metab*, 86, 4615-4617.

Ready-to-eat Cereals. (2008).

Nutrition Data. (2008). Retrieved February 13, 2009, from *http://www.nutritiondata.com/facts-C00001-01c20RL.html#nutrients-per-serving*

Calorie king Food Database. (2008). Retrieved February 12, 2008, from *http://www.calorieking.com/foods/category.php?subcat_id=193&category_id=8&brand_id=-1*

Reaven, G. M., Lithell, H., & Landsberg, L. (1996). Hypertension and associated metabolic abnormalities--the role of insulin resistance and the sympathoadrenal system. *The New England Journal of Medicine*, 334, 374-381.

Reaven, G.M. (1988). Banting lecture: Role of insulin resistance in human disease. *Diabetes*, 37, 1595-1607.

Reilly, J.J. (2005). Descriptive epidemiology and health consequences of childhood obesity. *Best Practice and Research in Clinical Endocrinology and Metabolism*, 19, 327-341.

Samaha, F. F. (2005). Effect of very high-fat diets on body weight, lipoproteins, and glycemic status in the obese. *Current Atherosclerosis Report*, 7, 412-420.

Savva, S.C., Tornaritis, M., Savva, M.E., Kourides, Y., Panagi, A., Silikiotou, N., Georgiou, C., & Kafatos, A. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index (2000). *The International Journal of Obesity and Related Metabolic Disorders*, 24, 1453-1458.

Shaw, D.I., Hall, W.L., & Williams, C.M. (2005). Metabolic syndrome: what is it and what are the implications? *Proceedings of Nutrition Society*, 64, 349-357.

Shils, M., Shike, M., Ross, A.C., Caballero, B., & Cousins, R.J. (ed.). (2005). *Modern nutrition in health and disease*. 10th ed. Baltimore: Lippincott Williams & Wilkins.

Siega-Riz, A.M., Popkin, B.M., & Carson, T. (1998). Trends in breakfast consumption for children in the United States from 1965-1991. *The American Journal of Clinical Nutrition*, 67, 748S-756S.

Software for the Statistical Analysis of Correlated Data (10.0). (2008). *Research Triangle Institute*, Research Triangle Park, NC.

Song, W.O., Chun, O.K., Kerver, J., Cho, S., Chung, C.E., & Chung, S.J. (2006). Ready-to-eat breakfast cereal consumption enhances milk and calcium intake in the US population. *Journal of the American Dietetic Association*, 106, 1783-1789.

Song, W.O., Chun, O.K., Obayashi, S., Cho, S., & Chung, C.E. (2005). Is consumption of breakfast associated with body mass index in US adults? *Journal of the American Dietetic Association*, 105, 1373-1382.

Song, Y., Cook, N.R., Albert, C.M., Van Denburgh, M., & Manson, J.E. (2009). Effect of homocysteine-lowering treatment with folic Acid and B vitamins on risk of type 2 diabetes in women: a randomized, controlled trial. *Diabetes*, 58, 1921-1928.

Statistical Analysis Software. (2007). Version 9.2. Cary, North Carolina.

Subar, A.F., Krebs-Smith, S.M., Cook, A., & Kahle, L.L. (1998)a. Dietary sources of nutrients among US adults, 1989 to 1991. *Journal of the American Dietetic Association*, 98, 537-547.

Subar, A.F., Krebs-Smith, S.M., Cook, A., & Kahle, L.L. (1998)b. Dietary sources of nutrients among US children, 1989-1991. *Pediatrics*, 102, 913-923.

Suitor, C.W., & Gleason, P.M. (2002). Using Dietary Reference Intake-based methods to estimate the prevalence of inadequate nutrient intake among school-aged children. *Journal of the American Dietetic Association*. 102, 530-536.

Sweeney, N.M., & Horishita, N. (2005).The breakfast-eating habits of inner city high school students. *The Journal of School Nursing*, 21, 100-105.

Timlin, M.T., Pereira, M.A., Story, M., & Neumark-Sztainer, D. (2008). Breakfast eating and weight change in a 5-year prospective analysis of adolescents: Project EAT (Eating Among Teens). *Pediatrics*, 121, e638-645.

Treviño, R.P., Fogt, D.L., Wyatt, T.J., Leal-Vasquez, L., Sosa, F., & Woods, C. (2008). Diabetes risk, low fitness, and energy insufficiency levels among children from poor families. *Journal of the American Dietetic Association*. 108, 1846-1853.

United States Department of Agriculture. Center for Nutrition Policy and Promotion . (2007). Diet quality of Americans in 1994-1996 and 2001-2002 as measured by the Healthy Eating Index- 2005. *Nutrition Insight,* 37.

United States Department of Agriculture. *Dietary Database of Vitamin A (mcg RAE) and Vitamin E (mg AT) for National Health and Nutrition Examination Survey (1999-2000). Agricultural Research Service, Food Surveys Research Group. Beltsville, MD. Retrieved October 28, 2009 from* http://www.ars.usda.gov/Services/docs.htm?docid=12088

United States Department of Agriculture. *Dietary Guidelines for Americans.* (2005). Retrieved October 28, 2009, from http://www.health.gov/dietaryguidelines/dga2005/document/default.htm

United States Department of Agriculture. *Dietary Guidelines for Americans.* (2005). *Shortfall Nutrients*. Part D Science base. Retrieved October 28, 2009, from http://www.health.gov/DIETARYGUIDELINES/dga2005/report/PDF/D1_Adequacy.pdf

United States Department of Agriculture. *Food and Nutrient Database for Dietary Studies, 1.0.* Retrieved October 28, 2009, from http://www.ars.usda.gov/Services/docs.htm?docid=12082

United States Department of Agriculture. *Food and Nutrient Database for Dietary Studies, 2.0.* Retrieved October 28, 2009, from http://www.ars.usda.gov/Services/docs.htm?docid=12083

United States Department of Agriculture. *Healthy Eating Index.* (2006). Center for Nutrition Policy and Promotion. Fact Sheet No. 1. Retrieved January 27, 2009, from *http://www.cnpp.usda.gov/Publications/HEI/healthyeatingindex2005factsheet.pdf.*

United States Department of Agriculture. *National Nutrient Database for Standard Reference, Release 16-1.* Retrieved October 28, 2009, from *http://www.nal.usda.gov/fnic/foodcomp/Data/SR16-1/sr16-1.html*

United States Department of Agriculture. *National Nutrient Database for Standard Reference, Release 18.* Retrieved October 28, 2009, from *http://www.nal.usda.gov/fnic/foodcomp/Data/SR18/sr18.html.*

United States Department of Agriculture. *National Nutrient Database for Standard Reference, Release 20.* Retrieved October 28, 2009, from *http://www.ars.usda.gov/ba/bhnrc/ndl*

United States Department of Agriculture. *School Breakfast Program* (1969-2009). Food and Nutrition Service. Retrieved October 26, 2009, from *http://www.fns.usda.gov/cnd/breakfast/AboutBFast/bfastfacts.htm*

Utter, J., Scragg, R., Mhurchu, C.N., & Schaaf, D. (2007). At-home breakfast consumption among New Zealand children: associations with body mass index and related nutrition behaviors. *Journal of the American Dietetic Association,* 107, 570-576.

Van den Boom, A., Serra-Majem, L., Ribas, L., Ngo, J., Pérez-Rodrigo, C., Aranceta, J., & Fletcher R. (2006). The contribution of ready-to-eat cereals to daily nutrient intake and breakfast quality in a Mediterranean setting. *Journal of the American College of Nutrition*, 25, 135-143.

Van der Heijden, A.A., Hu, F.B., Rimm, E.B., & Van Dam, R.M. (2007). A prospective study of breakfast consumption and weight gain among U.S. men. *Obesity (Silver Spring),* 15, 2463-2469.

Wang, Y., Rimm, E.B., Stampfer, M.J., Willett, W.C., & Hu, F.B. (2005). Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. *The American Journal of Clinical Nutrition,* 81, 555–563.

Whittaker, P., Tufaro, P.R., & Rader, J.I. (2001). Iron and folate in fortified cereals. *Journal of the American College of Nutrition*, 20, 247-254.

Willett, W.C. (1998). *Nutritional Epidemiology*, Second Edition Volume 30 pp. 20-23 & 322, New York, NY: Oxford University Press.

Wolfe, W.S., & Campbell, C.C. (1993). Food pattern, diet quality, and related characteristics of schoolchildren in New York State. *Journal of the American Dietetic Association.* 93, 1280-1284.

Wright, J.D., Borrud, L.G., McDowell, M.A., Wang, C.Y., Radimer, K., & Johnson, C.L. (2007). Nutrition assessment in the National Health and Nutrition Examination Survey 1999-2002. *Journal of the American Dietetic Association*, 107, 822-829.

Wurtman, R.J., Wurtman, J.J., Regan, M.M., McDermott, J.M., Tsay, R.H., & Breu, J.J. (2003). Effects of normal meals rich in carbohydrates or proteins on plasma tryptophan and tyrosine ratios. *The American Journal of Clinical Nutrition*, 77, 128-132.

Wyatt, H.R., Grunwald, G.K., Mosca, C.L., Klem, M.L., Wing, R.R., & Hill, J.O. (2002). Long-term weight loss and breakfast in subjects in the National Weight Control Registry. *Obesity Research*, 10, 78-82.

Yaney, G.C., & Corkey, B.E. (2003). Fatty acid metabolism and insulin secretion in pancreatic beta cells. *Diabetologia*, 46, 1297-1312.

Yannakoulia, M., Panagiotakos, D., Pitsavos, C., Skoumas, Y., & Stafanadis, C. (2008). Eating patterns may mediate the association between marital status, body mass index, and blood cholesterol levels in apparently healthy men and women from the ATTICA study. *Social Science Medicine*, 66, 2230-2239.

Zemel, M.B., Richards, J., Milstead, A., & Campbell, P. (2005). Effects of calcium and dairy on body composition and weight loss in African-American adults. *Obesity Research*, 13, 1218-1225.

Zhu, S., Heymsfield, S.B., Toyoshima, H., Wang, Z., Pietrobelli, A., & Heshka, S. (2005). Race-ethnicity-specific waist circumference cutoffs for identifying cardiovascular disease risk factors. *The American Journal of Clinical Nutrition*, 81, 409-415.

Zizza, C., Siega-Riz, A.M., & Popkin, B.M. (2001). Significant increase in young adults' snacking between 1977-1978 and 1994-1996 represents a cause for concern! *Preventive Medicine,* 32, 303-310.

Appendix A

List of Abbreviations

AACE = American Association of Clinical Endocrinologists

AHA = American Heart Association

AI = Adequate Intake

ANOVA = Analysis of Variance

AT = Alpha-Tocopherol

ATP (III) = Adult Treatment Panel (III)

BMI = Body Mass Index

BS = Breakfast Skippers

CADI = Computer-Assisted Dietary Interview

CAPI = Computer-Assisted Personal Interview

CDC = Centers for Disease Control and Prevention

CI = Confidence Interval

CSFII = Continuing Survey of Food Intakes by Individuals

CVD = Cardiovascular Disease

DFE = Dietary Folate Equivalent

DGA = Dietary Guidelines for Americans

DRI = Dietary Reference Intakes

EAR = Estimated Average Requirement

EGIR = European Group for the Study of Insulin Resistance

Equi = Equivalent

FFA = Free Fatty Acids

FNDDS = Food and Nutrient Database for Dietary Studies

HDL-C = High-Density Lipoprotein Cholesterol

HEI = Healthy Eating Index

HOMA = Homeostasis Model Assessment

IDF = International Diabetes Federation

IFG = Impaired Fasting Glucose

IGT = Impaired Glucose Tolerance

IR = Insulin Resistance

IOM = Institute of Medicine

Kcal = Kilocalories

LDL-C = Low-Density Lipoprotein Cholesterol

LSM = Least-squared Mean

LSSM = Least-squared Standard Error

LPL = Lipoprotein Lipase

MAR = Mean Adequacy Ratio

MEC = Mobile Examination Centers

MetS = Metabolic Syndrome

MUFA = Monounsaturated Fatty Acids

MVU = Masked Variance Units

n = Sample Size

NAR = Nutrient Adequacy Ratio

NCEP = National Cholesterol Education Program

NCHS = National Center for Health Statistics

NHANES = National Health and Nutrition Examination Survey

NHLBI = National Heart, Lung, and Blood Institute

NIH = National Institute of Health

OB = Other Breakfast

OR = Odds Ratio

PCOS = Polycystic Ovarian Syndrome

PIR = Poverty Income Ratio

PUFA= Polyunsaturated Fatty Acids

QUICKI = Quantitative Insulin Sensitivity Check Index

RAE = Retinol Activity Equivalent

RDA = Recommended Dietary Allowance

RTEC = Ready-to-eat Cereal

SAS = Statistical Analysis System

SE = Standard Error

SFA = Saturated Fatty Acids

SoFAAS = Solid Fat, Alcohol, and Added sugars

SUDAAN = Survey Data Analysis for Correlated Data

T2DM = Type 2 Diabetes Mellitus

US = United States of America

USDA = United States Department of Agriculture

VLDL = Very Low Density Lipoprotein

Vit = Vitamin

y = years of age

WC = Waist Circumference

WHO = World Health Organization

Appendix B

Exempt from Institutional Review Board

TWU
TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Office of Research
6700 Fannin Street
Houston, TX 77030-2343
713-794-2480 Fax 713-794-2488

September 11, 2008

Ms. Priya Ramesh Deshmukh-Taskar
Nutrition and Food Sciences-John Radcliffe Faculty Adv.
6700 Fannin Street
Houston, TX 77030

Dear Ms. Deshmukh-Taskar:

Re. *"National Patterns of Breakfast Consumption: Implications for Health"*

The above referenced study has been reviewed by the TWU Institutional Review Board (IRB) and was determined to be exempt from further review.

Any changes in the study must receive review and approval prior to implementation unless the change is necessary for the safety of subjects. In addition, you must inform the IRB of adverse events encountered during the study or of any new and significant information that may impact a research participant's safety or willingness to continue in your study.

Sincerely,

Dr. Gayle Hersch, Co-Chair
Institutional Review Board - Houston