Patterns of Sugars Intake, Total Energy Intake, and Body Mass Index in Healthy Individuals

by

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ABSTRACT

Background: Higher intake of carbohydrates in the evening and later eating times has been associated with higher total energy intake (TEI)[1-3] and higher risk of being overweight or obese.[1,4] Though existing evidence indicates a link between added sugars intake and increased body mass index (BMI), the effect of daily patterns of added sugars intake on TEI and BMI is unknown. Research on added sugars has relied on self-report dietary assessments with limited days of dietary data, resulting in unreliable estimates. The purpose of this thesis was to describe patterns of added sugars consumption, and to investigate the relationship between dietary sugars, eating patterns, TEI, and BMI using 15-days of dietary data from a feeding study. Methods: 40 participants age 18 to 70 years completed a 15-d highly controlled feeding study which imitated their normal diet, while recording meal times. Meals and snacks were coded based on participant identified, time-of-day, and meal content specific criteria. All consumed foods and beverages were carefully weighed and entered into the Nutrition Data System for Research (NDSR) for analysis. Pearson correlation, independent t-test, one-way repeated measures analysis of variance (ANOVA) with post hoc tests, and multiple linear regressions were used to investigate the association between patterns of added sugars and energy intake, as well as eating frequency (EF), with TEI and BMI. Results: 15-d median added sugars intake was 9.7% of total calories. The highest contribution to added sugars intake (% of g/d) came from snacks (44%) in women and from afternoon (39%) consumption in men. The highest contribution to TEI came from dinner (30%) and afternoon (34%) consumption in women, and from lunch (31%) or dinner (30%) and afternoon (35%) consumption in men. Total eating occasion (EO) frequency had a negative association with TEI (r = -

0.31) and no association with % energy from added sugars. In multivariate regression models, besides sex, % energy from beverages only (Adjusted R^2 = 0.41) and % added sugars from dinner (Adjusted R^2 = 0.39) were significant predictors of TEI, while none of the variables were associated with BMI. Conclusion: Changing one's pattern of eating, (EF and % energy from beverages only and % added sugars from dinner), may reduce TEI, potentially reducing BMI.

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CHAPTER 1

Based on data from 2011 - 2012, U.S. adults consume 14% of their total calories from added sugars,[5] which is well above the recommendations from the 2015-2020 Dietary Guidelines for Americans of $\leq 10\%$ total calories from added sugars.[6] According to the National Health and Nutrition Examination Survey (NHANES) from 2013-2014, 32.7% of U.S. adults were considered overweight and 37.9% were considered obese.[7] Evidence from randomized control trials has shown that excess calories from sugars intake, but not an isoenergetic exchange of dietary sugars with other macronutrients, is associated with weight gain.[8] Nonetheless, some evidence suggests that consuming fructose may decrease energy expenditure, thus promoting weight gain, independent of the extra calories it provides.[9,10] Resulting overweight and obesity then increase the risk of chronic diseases and adverse health outcomes, such as diabetes mellitus (DM), cardiovascular disease (CVD), and some cancers.[10,11] In order to successfully lower the obesity rate in the U.S., we need to fully understand the factors that increase the risk of weight gain, so we can create successful intervention programs for at risk populations.

Higher intake of total carbohydrates, protein, and fat in the evening and eating later in the day have been shown to be associated with higher TEI[1-3] and higher risk of being overweight or obese.[1,4] More frequent eating has also shown to be associated with higher TEI.[12,13] While some studies found a positive association between EF and BMI,[14-16] others have found that a higher EF was associated with reduced overweight or obesity.[17,18] A study done in a representative sample of the Australian population age two and up found that, out of all meals, snacks were the greatest contributors of added sugars (48.3%), followed by breakfast/brunch (20.6%).[19] In the U.S., the amount of energy derived from snacks has increased over the period 1971 to 2010;[20,21] energy from snacks increased from 296 ± 7 to 438 ± 8 kcal in women, and from 502 ± 15 to 634 ± 13 kcal in men.[20] A review of literature has shown that overall snacks are providing a similar energy intake as breakfast or more in most countries.[22]

So far, studies have investigated timing of total carbohydrate intake,[1,23] but not total or added sugars, in association with total energy and overweight or obesity. Furthermore, no evidence is available on the effect of patterns of sugars intake throughout the day on TEI and BMI in the U.S. population. A major limitation in this area of research is that the evidence is based on self-reported dietary intake and eating behaviors (i.e., meal times and meal type). Studies looking at eating patterns, specifically meal times and frequency, have utilized 24-hour dietary recalls (24HDR), 7-day food diaries, and food frequency questionnaires (FFQ) in combination with additional questionnaires (Meal Patterns Questionnaire or single item questionnaires).[24] These instruments are subject to error due to memory errors, misreporting, and the use of invalid or unreliable meal pattern questions or questionnaires.[24,25] Food diaries and 24HDR are superior to the FFQ in combination with a questionnaire, since they measure actual daily intake, however, taking multiple days of measurement is necessary in order to assess usual intake and eating behavior.[25] This is difficult due to high participant burden and high cost, which leads to the use of more cost effective, brief, and unreliable methods when assessing meal patterns.[25]

Ultimately, eating patterns may be an important determinant of total caloric intake and obesity. However, research looking specifically at the eating patterns of sugars in relation to TEI, and BMI, dependent or independent of energy intake is lacking. This research study will use data from a 15-day highly controlled feeding study, which simulates participants' usual diet and has detailed information on the time and content of each meal. If there is a significant association between dietary sugars intake, eating patterns, and BMI, this could potentially lead to the identification of overall eating patterns and patterns of sugars that are less likely to adversely affect BMI.

PURPOSE OF THE STUDY

The objective of this highly controlled feeding study was to describe the patterns of added sugars consumption, and to study the association between dietary sugars, eating patterns, TEI, and BMI, in healthy adults age 18-70 years consuming their usual diet. Each participant was fed their usual diet over the 15-day feeding study previously assessed by two 7-day food diaries. During the feeding study, participants were allowed to eat as much as they wanted, but only from the foods and beverages provided by the metabolic kitchen and returned all leftovers the following day so the exact amount consumed could be calculated. Participants also recorded the timing of each meal and snack consumed. This controlled study design allowed us to overcome the limitations of previous research, since we relied on 'true' dietary intake, and have information on meal timing and the composition of meals for a 15-day period.

AIMS AND HYPOTHESES

- **Aim 1**: To describe patterns of added sugars consumption in healthy adults living in the Phoenix metro area. (e.g. frequency of intake, proportion of added sugars intake by meals/snacks, distribution of added sugars intake by time-of-day).
    - **H1.1**: Increased eating frequency (EF) is associated with increased added sugars intake and TEI.
    - **H1.2**: Snacks are bigger contributors to added sugars intake compared to main meals (breakfast, lunch, or dinner).
    - **H1.3**: Snacks contribute the highest % energy from added sugars compared to main meals.
    - **H1.4**: Foods and beverages consumed at night are bigger contributors to added sugars intake compared to foods and beverages consumed at other times of the day (morning, afternoon, and evening).
    - **H1.5**: Foods and beverages consumed at night contribute higher % energy from added sugars compared to those consumed at other times of day.
- **Aim 2**: To investigate the association between patterns of added sugars consumption and energy intake.
    - **H2.1**: The amount of added sugars from snacks will be a significant predictor of TEI.
    - **H2.2**: Added sugars and energy intake at night will be associated with a higher TEI.

Aim 3: To investigate the association between patterns of added sugars consumption and BMI, and the role of energy on the association (energy dependent or independent of energy).

- **H3.1**: There is a relationship between EF and BMI.
- **H3.2**: Added sugars intake from snacks are associated with higher BMI.
- **H3.3**: Added sugars and energy intake at night are associated with a higher BMI independent of TEI.

DEFINITIONS

- **Healthy weight:** BMI <25 kg/m^2
- **Overweight:** BMI of 25-29.9 kg/m^2
- **Obesity:** BMI $\geq$ 30 kg/m^2
- **Added sugars:** Sum of sugars (monosaccharides and disaccharides) added to foods or beverages during preparation or processing. This includes glucose, fructose, sucrose, high-fructose corn syrup, molasses, brown sugar, cane sugar, etc. [26]
- **Total sugars:** Sum of monosaccharides (glucose, fructose, galactose) and disaccharides (sucrose, lactose, maltose) either naturally-occurring or added to food.[27]
- **Morning:** 5:00 am - 10:59 am
- **Afternoon:** 11:00 am - 3:59 pm
- **Evening:** 4:00 pm - 7:59 pm
- **Night:** 8:00 pm - 4:59 am

- **Main meal:** Eating occasion (EO) identified by participant as breakfast, lunch or dinner between these times (Breakfast: 5:00 am-10:59 am, Lunch: 11:00 am-3:59 pm, and Dinner: 4:00 pm-12:00 am) **OR** an EO identified by the participant as snack while composed of meal foods and meal consists of 3 or more food groups and provides similar amount of calories to a typical meal for the participant
- **Snack:** EO identified by participant as snack between these times (5:00 am-10:59 am, 11:00 am-3:59 pm, and 4:00 pm-12:00 am) **OR** an EO that occurs from 12:00 am – 4:59 am **OR** an EO identified as a meal by participant while composed of snack foods only or consists of 1-2 food groups **OR** an EO that consists of leftovers from a consumed meal and provides substantially fewer calories than a typical meal for the participant.

DELIMITATIONS

- Study population: Healthy individuals age 18-70 years. Excluded people with DM (Type I or Type II), kidney disease, bladder incontinence; under a dietary restriction due to a medical condition; participants who have lost or gained weight within four months; having allergy to sunscreen, aminobenzoate potassium (POTABA) or para-amino benzoic acid (PABA); participating in a diet research study within four months; and breastfeeding or pregnant women. As for laboratory values, participants were also excluded if their HbA1c ≥5.7% or fasting blood glucose ≥100 mg/dl.
- Site of study: Phoenix metropolitan area

LIMITATIONS

- Use of a convenience sample
- Participants self-report meal and snack times
- Small sample size
- Cannot determine causality due to cross-sectional study design

CHAPTER 2

REVIEW OF LITERATURE

INTRODUCTION

Added sugars consumption in the U.S. far exceeds current dietary recommendations of ≤ 10% energy from added sugars.[6] Overweight and obesity prevalence in the U.S. is alarmingly high,[7] with obesity currently still on the rise[28] and linked to many chronic diseases.[10,11] It has been established that there is a relationship between sugars and weight gain, however it is unclear whether that relationship is due to the sugars per se[9,10] or due to an increase in TEI.[8,10,11] In regards to eating patterns, the relationship between EF and BMI is inconclusive.[14-18,29] However, research investigating the relationship between meal timing and BMI is showing that eating later in the day is associated with an increase in BMI.[1,4] Research investigating patterns of added sugars consumption, and their relationship to BMI, independent and dependent of total energy, are lacking. For the purpose of this review, we will focus on obesity and TEI and their contributors: eating patterns (EF and meal timing) and added sugars intake.

ADDED SUGARS CONSUMPTION IN THE U.S.

Added sugars consumption in the U.S. has increased over time and is alarmingly high. Powell et al investigated trends in added sugars intake from 1977-2012 using data from six nationally representative surveys using 24HDRs to assess diet.[5] In 1977-1978, adults consumed 12% of total calories from added sugars.[5] In 2011-2012, added sugars consumption had increased to 14% in adults.[5] However, it wasn't a steady increase. The results from this study showed that from 2003-2004 the percentage of total calories from added sugars for adults (15%) was even higher than what it was from 2011-2012 (14%).[5] That slight decrease from 2003-2004 to 2011-2012 may have been due to the decrease in added sugars intake from beverages in adults (199 kcal to 164 kcal).[5] Despite that decrease in the consumption of added sugars from beverages from 2003-2004 to 2011-2012, research is showing that the consumption of sugar sweetened beverages (SSB) is still high. According to a report by Rosinger et al based on NHANES data, it was found that from 2011-2014, around half of adults in the U.S. had one or more SSB per day.[30] Adults consuming SSB, consumed on average 6.5% of their total calories from SSB per day.[30] In these analyses, authors used self-reported diet and the USDA food composition database wasn't regularly updated, which may have resulted in misinformation about the added sugar content of products.[5,30] Also, both studies only used one 24HDR in their analysis, which means they did not account for day to day variability in subject's diet.[5,30]

SOURCES AND DEFINITIONS OF SUGARS

Sugars are found in a variety of food and beverage sources, and there are numerous types and definitions. There are two kinds of simple sugars: monosaccharides and disaccharides.[31] Monosaccharides can't be broken down further and include glucose, fructose, and galactose.[31] Disaccharides are made up of two monosaccharides that are joined by glycosidic bonds and they include sucrose (glucose and fructose), lactose (galactose and glucose), and maltose (glucose and glucose).[31] Food sources of simple sugars include honey, fruit, vegetables, SSB, baked goods, candies, milk, milk products, etc.[27,32] Sugars are further categorized by total sugars, free sugars, added sugars, intrinsic sugars, extrinsic sugars, and non-milk extrinsic sugars. 'Total sugars' are defined as the total amount of monosaccharides (glucose, fructose, and galactose) and disaccharides (sucrose, lactose, and maltose) either naturally-occurring or added to food.[27,33] 'Free sugars' are defined as all monosaccharides and disaccharides added to foods, including sugars that are found in fruit juices, syrups, and honey naturally, and it is a term used by the World Health Organization (WHO).[27] The term 'added sugars' is used to describe sugars (monosaccharides and disaccharides) that are added to food or drinks during food preparation, food processing, or at the table in the U.S.. This includes sugars, syrups, and caloric sweeteners, but not sugars from honey or fruit juice.[26] Intrinsic sugars are sugars found naturally in foods, like fruits and vegetables. The definition for intrinsic sugars clearly states that it only includes sugars enclosed in cells of unprocessed foods. Sugars that are naturally found in milk represent milk sugars.[27] The term 'Non-milk extrinsic sugars' is similar to 'free sugars' and include all sugars that are added to food during processing or added at the table, including sugars from fruit juices, honey, and syrups.[27] With this being said, the definitions for total, added, and free sugars are not standardized, and many nutrient databases and organizations calculate added sugars in multiple different ways.[34] For example, NDSR calculates added sugars from total sugars and by available carbohydrates.[34] This tends to make it difficult to properly analyze and compare results from studies measuring sugars intake.[27,34]

DIETARY RECOMMENDATIONS FOR SUGARS

Dietary recommendations for sugars consumption (free and added) have become more restrictive over the years. In 2002 the Institute of Medicine recommended that less than 25% of total calories come from added sugars.[35] In 2009, the American Heart Association recommended that women should consume less than 100 kcal (approximately 6 tsp) and men less than 150 kcal (approximately 9 tsp) from added sugars per day.[36] Currently, WHO recommends a restriction of intake to be < 10% total calories from free sugars.[37] WHO also suggests an additional decrease in free sugars intake to < 5% of total calories for a further reduction in disease risk.[37] Similar to the WHO recommendation, in 2015, the United States Department of Agriculture (USDA) Dietary Guidelines for Americans 2015-2020 recommended that Americans consume ≤ 10% total calories from added sugars.[6]

The recommendations for sugars are difficult for the general public to meet. A research study by Erickson and Slavin[34] analyzed sample meal plans produced by the Academy of Nutrition and Dietetics (AND) and the USDA that were designed for the general public as a tool to help meet the current dietary recommendations. They analyzed 7 days from a 2-week sample menu from the USDA, and 5 days from the 1800 kcal 5-day menu from the AND nutrition care manual. With the use of Nutrient Data System for Research (NDSR), it was concluded that the meal plans produced by the USDA went over the more restrictive recommendations from WHO, with an average of 8.7% total energy from free sugars, but met the recommendations from the USDA, with an average of 5.1% total energy from added sugars.[34] As for the meal plans from AND, they were under the recommendations from WHO and the USDA, with an average of 3.1% total energy from both free and added sugars.[34] It was determined that the USDA went over the recommendations for free sugars because they used fruit juice as a beverage on many days, where the AND didn't use any fruit juice in their menu.[34]

DETERMINANTS OF HIGH ADDED SUGARS INTAKE

There are numerous sociodemographic and behavioral factors associated with high added sugars intake in adults. Using data from the 2005 and 2010 National Health Interview Survey (NHIS)[38,39] it was found that being younger, having a lower family income, lower education, and being African American were all associated with consuming more added sugars in both men and women,[38,39] and that added sugars intake was higher in men than in women.[38] Further, having low physical activity was also associated with a higher added sugars intake.[39] More specifically, Park et al[39] found that younger adults (18 to 24 years) had an increased risk of high added sugars intake compared to older adults (≥ 60 years) [men: OR (95% CI) = 18.52 (13.41 - 25.58); women: OR (95% CI) = 9.91 (7.54 - 13.01)]. Furthermore, Hispanic men and Black women were more likely to be high added sugars consumers compared to their white counterparts [Hispanic men: OR (95% CI) = 1.11 (0.91-1.35); Black women: OR (95% CI) = 1.22 (1.03 - 1.45)]. They also found that adults with lower education (< high school), lower income ($75,000-$99,999 in men and < $35,000 in women), and lower physical activity (0 times/week) had increased odds of having a high added sugars intake (≥22.0 tsp/d) compared to adults with a higher education level (≥ college graduate) [men: OR (95% CI) = 2.06 (1.63 - 2.59); women: OR (95% CI) = 1.82 (1.47 - 2.26)], a higher income (≥ $100,000) [men: OR (95% CI) = 1.30 (1.00 - 1.69); women: OR (95% CI) = 1.33 (1.09 - 1.62)], and increased physical activity (> 5 times per week) [men: OR (95% CI) = 1.22 (1.04 - 1.44); women: OR (95% CI) = 1.64 (1.42 -1.89)] respectively. In comparison, a study by Rosinger et al[30] found that younger adults age 20-39 years on average consumed significantly more calories from SSB per day (204 kcal) than older adults age 40-59 years (141 kcal) and 60 years and over (68 kcal) ($p < 0.05$).[30] Overall, men consumed significantly more calories from SSB (179 kcal) than women (113 kcal), regardless of age ($p < 0.05$).[30] In regards to race, it was found that Hispanics (men: 215 kcal; women: 142 kcal) and African Americans (men: 213 kcal; women: 179 kcal) consumed significantly more calories from SSB than whites (men: 167 kcal; women: 97 kcal) and Asians (men: 90 kcal; women: 51 kcal).[30] Limitations in both Thompson et al's[38] and Park et al's[39] studies were that the estimate of added sugars intake were based on dietary screeners instead of a more detailed dietary assessment instrument (e.g., 24HDR or food diary), the amount of calories from added sugars couldn't be determined due to the lack of energy intake estimates, and that environmental factors (increased advertising, increased vending machine availability, and bigger restaurant portion sizes) were not included in their data analyses. Further, while Rosinger et al used a more reliable dietary assessment method (24HDR), they only collected dietary data from one day.[30] Overall, the results from these studies were similar in regard to the identification of demographic and socioeconomic determinants of high added sugars intake, which included being male, African American or Hispanic, younger, and having a lower education and income. These determinants can be utilized to help identify populations with high added sugars intake, which can be the focus populations in future research regarding added sugars consumption in U.S. adults.

ADDED SUGARS AND BMI/WEIGHT GAIN

Current research is suggesting that added sugars intake is a determinant of weight gain, but it is unclear whether it is the added sugars per se resulting in the weight gain[9,10] or the increased energy intake resulting from the added sugars intake.[8]

Two intervention studies[40,41] found that participants consuming high amounts of sucrose had an increase in body weight and energy intake, while those consuming high amounts of artificial sweeteners had a decrease in body weight and energy intake. Sorensen et al conducted a 10 week single blind intervention trial with healthy overweight adults, with one group receiving supplementation of sucrose (n = 12) or artificial sweeteners (n = 10) from foods (20%) and beverages (80%) while consuming their normal diet.[40] It was found that those in the sucrose group had an increase in both body fat (1.4 ± 0.6 kg) and fat mass (1.2 ± 0.6 kg), while those in the artificial sweetener group had a decrease in body fat (-1.2 ± 0.6 kg) and fat mass (-0.9 ± 0.6 kg).[40] Further, at week 10, the sucrose group had higher overall energy intake (14.6 MJ), when compared to the artificial sweetener group (11.3 MJ).[40] Reid et al did a 4 week intervention trial including healthy normal weight women (n = 133) with sucrose or aspartame drink supplementation that provided 1,800 kJ and 105 g carbohydrates total per day.[41] Similarly, it was found that a majority of women in the sucrose group had an increase in weight and daily energy, while most women in the aspartame group had a decrease in weight and daily energy.[41] Limitations of these studies include the small sample size, low generalizability, and that the participant's individual diets were not the same in regards to macronutrient proportions.[40,41] Despite these limitations, these studies suggest that increased added sugars intake can lead to weight gain, and increased energy intake from high sugar foods and beverages may play a role in that mechanism.

In contrast, two studies by Stanhope et al[42] and Cox et al[43] found that participants consuming high amounts of fructose had an increase in adiposity and decreased resting energy expenditure, while those consuming high amounts of glucose did not. More specifically, a double-blinded parallel arm study showed that the high fructose group (n = 17), which consumed fructose-sweetened beverages providing 25% of energy requirements for 10 weeks, but not the high glucose group (n = 14), had an increase in visceral adiposity and de novo lipogenesis in overweight and obese adults.[42] It was also found that high fructose consumption led to a significant decrease in net postprandial fat oxidation (-33.7% ± 4.3) and resting energy expenditure (REE) (-0.09 ± 0.04).[43] However, these results should be interpreted with caution, since this study had a small sample size, the amount of added sugars consumed in this study were over the mean intake of added sugars consumed by the general public (15%), and that glucose and fructose are usually consumed together in the form of sucrose or high fructose corn syrup in both food and beverage sources.[42,43] Despite these limitations, these studies indicate that added sugars may be contributing to obesity, independent of energy.

OVERWEIGHT AND OBESITY (BMI) TRENDS IN THE U.S.

BMI is used to classify adults into one of three categories: overweight (25-29.9 kg/m^2), obesity (≥30 kg/m^2), and extreme obesity (≥40 kg/m^2).[7] Adult obesity and extreme obesity prevalence in the U.S. is on the rise, while overweight prevalence is remaining relatively stable. A cross-sectional study by Kranjac et al[44] looked at BMI trends in adults ≥20 years (n=59,627) in the U.S. by analyzing data from NHANES surveys from 1971-2012. It was found that obesity, extreme obesity, and BMI had all significantly increased during that time period.[44] More specifically, the average BMI had increased from 25.7 kg/m^2 in 1971 to 28.7 kg/m^2; obesity increased by 15% (from 15 ± 1% to 29 ± 1%); and extreme obesity increased by 5% (from 1 ± <0.1% to 6 ± 1%).[44] According to data on U.S. adults ≥ 20 years from NHANES 2013-2014, overweight prevalence has stayed relatively stable, from 33.1% in 1988-1994 to 32.5% in 2013-2014, while obesity and extreme obesity are still on the rise (obesity (37.7%); extreme obesity (7.7%).[7]

Furthermore, a data brief by Hales et al looked at the prevalence of obesity among adults and youth in the U.S. from 2015-2016, and found that the prevalence of obesity had increased even higher, to 39.8% in adults.[28] However, it was found that adults in the 40-59 years age group had a higher prevalence of obesity (42.8%) than adults in the 20-39 years age group (35.7%).[28] By race, it was seen that African Americans (46.8%) and Hispanic adults (47.0%) had a higher prevalence of obesity than White (37.9%) and Asian adults (12.7%).[28] Although there was a significant increasing trend in obesity from 1999-2016, there was not a significant increase in obesity prevalence from the 2011-2014 report (37.7%) and the 2015-2016 report in adults (39.6%).[28,45] In summary, the available literature demonstrates that the prevalence of obesity and extreme obesity continues to be on the rise in U.S. adults, while overweight prevalence is remaining relatively stable at a high rate. The largest prevalence of obesity has been found among Hispanic and African American populations and adults 40-59 years of age.

DETERMINANTS OF OVERWEIGHT AND OBESITY

There are numerous demographic and socioeconomic factors associated with obesity in adults. Three cross-sectional studies[46-48] collectively found that employment, education level, race, age, gender, marital status, occupation, and income have an association with increased BMI and obesity risk. More specifically, in a convenience sample of adults from Hartford, Connecticut (n = 176), Martin et al[46] found that food insecure adults had more than double the risk of being obese compared to adults that were food secure [OR (95% CI): 2.45 (1.15 - 5.25)]. Further, in a representative sample of the English population (n = 15,061), Wardle et al[47] found that men and women with a lower education level (age leaving education $\leq$ 14 years) had a 77% (95% CI: 1.30 - 2.40) and 81% (95% CI: 1.36 - 2.41) increase in obesity risk, respectively, compared to men and women with a higher education level (age leaving education $\geq$ 19 years). Also, older men and women age 55-64 years were over three times as likely to be obese when compared to young adults age 16-24 years [men: OR (95% CI): 3.58 (2.42 - 5.30); women: OR (95% CI): 3.04 (2.18 - 4.22)].[47] As for women, black women were almost three times as likely to be obese compared to white woman [OR (95% CI): 2.98 (2.06 - 4.30)]. Women that were separated, widowed, or divorced had a 23% increase in obesity risk compared to married women (95% CI: 1.07-1.41). Women that had a unskilled manual occupation were three times as likely to be obese when compared to women who had a professional occupation [OR (95% CI) 3.02 (1.41 - 6.47)].[47] Furthermore, Ball et al[48] found that in a representative sample of the Australian population (n = 8,667) women who had low employment (unemployed and receives government pension or benefits) were 1.4 times more likely to be overweight compared to women with high employment (i.e., employed and does not receive pension/benefits) [OR (95% CI): 1.4 (1.2 - 1.7)]. They also found that women with medium housing (one to three bedrooms and a renter or purchaser of an apartment or home) were 1.3 times more likely to be overweight compared to women who had high housing (four or more bedrooms and owner of a home) [OR (95% CI): 1.3 (1.1 - 1.5)].[48] For men, it was found that those with a low family unit (married, one income, and left school before age 15) had a 60% higher risk of being overweight when compared to men with a high family unit (single, had a shared income, and left school after age 18) [OR (95% CI): 1.6 (1.4 - 2.0)].[48] Though these results cannot be generalized to the general U.S. population, these studies still indicate that socioeconomic factors play a role in overweight and obesity risk.

EATING PATTERN TRENDS IN THE U.S.

Available literature demonstrates that eating patterns in the U.S. have evolved over time, with an increase in EF, a decrease in time between meals, and later meal and snack times. A cross-sectional study by Kant et al[49] used data on U.S. adults (n = 39,094) from NHANES 1971-1975 and 1999-2002 and found that eating episodes in women slightly increased from 4.90 ± 0.03 to 5.04 ± 0.04 (p_{trend} = 0.002) and decreased in men from 5.22 ± 0.05 to 5.09 ± 0.05 (p_{trend} = 0.20). However, a study by Popkin et al[21] using data from four U.S. data sets from 1977-2006 on U.S. adults ≥ 19 years (n = 36,846) found that the mode frequency of EO's increased from three EO's per day to about five EO's per day and that the median number of total EO's increased by one EO ($p \leq 0.001$) in adults over 30 years. The increase in the median number of total EO's predominantly occurred between 1998-2006 for all percentiles.[21] The use of different national dietary surveys in Kant et al's[49] compared to Popkin et al's[21] study may explain the contrast in EO values from the 1970's. Overall, these studies show that shifts in U.S. EF patterns were inconclusive, ranging from a slight increase in women to a large increase in the overall U.S. population.

There has also been a slight rise in snacking prevalence and the number of snacks per day in U.S. adults. A study by Piernas et al (n = 44,754) found that snacking prevalence in adults increased from 71% in 1977 to 97% in 2003-2006.[50] In adults, number of snacks consumed per day slightly decreased from 1971-2002 (2.3 ± 0.04 to 2.1 ± 0.04; $p_{trend} = 0.001$),[49] and then slightly increased by 1 snack/day from 1997-2006, resulting in 2.23 ± 0.02 snacks consumed per day for men and women.[50] Similarly, a study by Kant et al (n = 62,298) found that the number of snacks consumed in women increased (2.09 ± 0.04 to 2.30 ± 0.04; $p_{trend} < 0.0001$), but decreased in men (2.45 ± 0.05 to 2.23 ± 0.03; $p_{trend} = 0.004$) from 1971-2010.[20] Both studies reported a slight increase in snacking prevalence and frequency, specifically in women.

In regards to meal timing, Popkin et al found that there was a 1 hour decrease in time between EO's from 1977-1978 and 2003-2006; with it currently being approximately 3.5 hours for adults.[21] Similarly, a cross-sectional study by Kant et al[20] found a decrease in the average time (mean hours ± SE) between eating episodes from 1971-1974 to 2009-2010 in both men (2.75 ± 0.02 to 2.67 ± 0.02; $p_{trend} < 0.0001$) and women (2.74 ± 0.01 to 2.51 ± 0.02; $p_{trend} < 0.0001$).[20] They also found that meals (breakfast and lunch) and snacks (pre-breakfast snack, morning snack, and the afternoon snack) were being eaten later in the day.[20] Overall, these studies present a shift in meal timing, decreased time between EO's and later meal times.

Limitations of these studies include that they used different definitions for snacks. Most studies used a participant identified definition for snacks.[21,49] However, some studies used a participant identified definition in combination with additional criteria: separating food and beverage only[50] or defining snacks as EO occurring before or after participant identified meals.[20] Furthermore, all studies only used one[20,49] to two[21,50] days of self-reported intake (24HDR or FR). Due to this, variability of eating patterns may not have been accurately captured and misreporting could have occurred. A limitation of studies that utilized NHANES surveys are that there was a change in the methodology for collecting 24HDR from 2002 onward.[20,21,49,50] Despite these limitations, all studies had large sample sizes representative of the U.S. population.[20,21,49,50] It can be concluded that eating patterns may be changing over time, with a slight increase being seen in EF and snacking, a decrease in time between EO's, and later eating times for meals and snacks.

ENERGY INTAKE TRENDS IN THE U.S.

Research is showing that TEI is slightly decreasing, with more energy coming from snacks and less energy coming from main meals. Both Kant et al[49] and Ford et al[51] found that TEI had increased in U.S. adults by approximately 230 to 300 kcal from 1971-2004 (1971-2002: 1968 ± 20 kcal to 2205 ± 16 kcal[49] and 1971-2004: 1994.7 ± 24.1 kcal to 2298.4 ± 48.1 kcal[51]) and then slightly decreased by approximately 20 kcal from 2004-2010 (2003-2004: 2298.4 ± 48.1 kcal and 2009-2010: 2280.9 ± 33.0 kcal).[51]

Though TEI has been slightly decreasing since 2004, energy from snacks has increased over time. Kant et al[49] and Piernas et al[50] found that energy per snack (kcal/snack) has increased approximately 49 kcal from 1971 to 2002 (185 ± 4 kcal to 234 ± 4 kcal; $p < 0.0001$)[49] and approximately 82 kcal from 1977 to 2006 (144 ± 3.15 kcal to 226 ± 3.68 kcal; $p < 0.01$).[50] Using data from large representative dietary surveys, Piernas et al[50] and Popkin et al[21] found that total energy from snacking (food and beverages) has also increased by approximately 220-280 kcal from 1977 to 2006 (357 ± 5.2 kcal to 579 ± 7.6 kcal[50] and 196 ± 5.1kcal to 472 ± 8.6 kcal[21]). The drastic difference in total energy from snacking from 1977 may have been due to differences in snack and meal coding between studies. When separating snacking into food only and beverages only, Popkin et al[21] found that energy from foods increased by 180 kcal (126 ± 3.3 kcal to 307 ± 6.2 kcal) and energy from beverages by 100 kcal (70 ± 2.2 kcal to 166 ± 4.7 kcal) from 1977-2006, with food sources contributing more energy to total snack energy. Further, Kant et al[20] found that from 1971 to 1974 and 2009 to 2010, energy intake from snacks increased by approximately 135 kcal (men: 502 ± 15 kcal to 634 ± 13, $p_{trend} < 0.0001$; women: 296 ± 7 kcal to 438 ± 8, $p_{trend} < 0.0001$).

While energy from snacks is increasing over time, the percent energy from main meals is decreasing. In the period 1977-2006, among adults, there was a decrease in the percent energy intake from meals by 6% (from 82% to 76%).[50] Similarly, Kant et al[20] found that from 1971-1974 to 2009-2010, there was a decrease in percent energy from main meals in both men (80 ± 0.4% to 77 ± 0.4%, $p_{trend} < 0.0001$) and women (82 ± 0.4% to 77 ± 0.4%, $p_{trend} < 0.0001$).

Main limitations of these studies include different meal and snack definitions among studies and the use of one to two days of dietary data.[20,21,49-51] Despite these limitations, all studies used study populations representative of the general U.S. population.[20,21,49-51] It can be concluded from current research that total energy has started to decrease, followed by an increase in energy from snacks and a decrease in energy from main meals in U.S. adults.

MEAL AND SNACK DEFINITIONS

Currently, there is no standardized definition for meals or snacks. According to a review by Leech et al[24], meals can be described based on the context of the meal, the format of the meal, or patterning of the meal. The construct chosen to describe a meal depends on the variables being measured. For example, if one was measuring the frequency of meals and snacks, they would be looking at patterning.[24] Focusing on common meal definitions, there are four types: neutral, food-based classification (FBC), time-of-day, and participant-identified.[24] For the neutral approach, all eating occurrences are defined as an eating event and then standardized criteria are used to describe it.[24] For this meal and snack definition additional criteria have commonly been used: minimum-energy criterion for meals (210 kJ), whether to include beverage EO, and specific time intervals between EO, ranging anywhere from 15 minutes to 1 hour.[24] These additional criteria have also been used in participant identified and time-of-day definitions in order to successfully separate EO.[24] The neutral definition for meals and snacks is useful when comparing meal patterns from different cultures. Food-based classification separates the food eaten into groups based on their nutritional profile and then classifies them to a certain eating occurrence based on the foods. This definition of meals and snacks is useful if the variable being measured is meal patterns and meal content.[24,52,53] Next, the time-of-day approach defines meals and snacks based on the time the meal or snack was consumed. For example, a meal is defined as the largest EO to occur between the following times: 6:00 am - 10:00 am, 12:00 pm - 3:00 pm, and 6:00 pm - 9:00 pm. A snack is defined as an EO not occurring between any of those times or a smaller EO.[24,53] Though this definition is easier to use, it may be biased towards normal eating patterns, and is less applicable when meals are eaten at odd times of the day.[24] Lastly, for participant-identified meals and snacks, the participants record whether the EO was a meal or snack according to their preference.[24] This definition isn't standardized since it varies per participant. With that being said, future research needs to focus on standardizing the definition for meals and snacks, since the definitions used in research can directly affect the analysis and final results of studies investigating meal types, as well as comparability between studies' findings.

SNACKING AND HEALTH

Snacking has shown to have a positive effect on health, depending on snack frequency (SF) and snack composition.[54] Research looking at snacking and the metabolic response has found that increased SF is associated with better blood glucose control and insulin response,[55,56] decreased triglyceride levels,[56,57] and decreased total cholesterol and LDL cholesterol levels[56-58]. Macronutrient content and food type may also play a role in the metabolic response to snacking.[54] For example, high carbohydrate snacks were found to increase glucose and insulin levels, and to reduce plasma fatty acids when compared to no snacks.[59] Also, high protein snacks increase satiety and also reduce plasma fatty acid concentrations compared to no snacks.[59] Common snack foods in the U.S. include desserts, candies, and salty foods like popcorn, pretzels, chips, and crackers.[60] A shift to healthier snacks like fruits, vegetables, nuts, whole grains, low-fat dairy, etc., with an emphasis on a combined macronutrient profile may lead to an increase in health outcomes coming from snacking, however, more research is needed in this area.[60]

EATING FREQUENCY AND ENERGY INTAKE

Studies investigating the relationship between TEI and eating patterns have reported a positive relationship between EF and TEI. Three cross-sectional studies[13,61,62] found that EF is positively associated with TEI. Kerver et al[13] used data collected by a 24HDR from NHANES III (1988 to 1994) in order to investigate the association between meal and snack patterns and energy intake in U.S. adults ≥ 20 years (n = 15,978). Multivariate adjusted nutrient intakes by EF were calculated, controlling for age, ethnicity, sex, income, alcohol intake, smoker status, supplement use, physical activity, and BMI.[13] It was found that EF was positively associated with energy intake ($p < 0.0001$).[13] Subjects who ate three meals a day had the lowest TEI (2,009 ± 46.2 kcal), while subjects who ate three meals in addition to ≥ two snacks per day had the highest TEI (2,461 ± 25.4 kcal).[13] A cross-sectional study by Zhu et al[61] used data collected by the first 24HDR from NHANES 2009-2010 and 2011-2012 to investigate the relationship between EF and energy intake in U.S. adults (n = 7,791). One unit increase in EF was associated with a statistically significant increase in energy intake (kJ) in both men ($\beta = 264.7$; SE = 18.9; $p < 0.001$) and women ($\beta = 204.4$; SE = 9.6; $p < 0.001$).[61] Furthermore, a cross-sectional study by Mills et al[62] investigated the association between behavioral factors and energy intake in middle aged women (n = 1,099) using data from a 1-day food diary. They found that an increase in EF resulted in an increase in energy intake in all women (1-3 EO: 1,864 ± 583 kcal and ≥ 7 EO: 2,348 ± 730 kcal; $p < 0.0001$), while there was a weak positive association between EF and total energy ($r = 0.20$; $p < 0.0001$).[62] The main limitation from these studies were that that they all used one day of dietary data, which means the variability in energy intake and EF was not accurately captured.[13,61,62] Despite this limitation, these studies still demonstrate that EF is positively associated with TEI.

EATING FREQUENCY AND BMI

Studies investigating the relationship between EF and BMI are inconclusive, with some studies showing a positive association,[14-16] some a negative association,[17,18] or no association at all.[29]

Studies by Howarth et al,[16] Murakami et al,[14] and Kahleova et al[15] found that an increased EF was associated with overweight and obesity[14,16] and an increase in BMI.[15] In a cross-sectional analysis of NHANES 2003-2012 dietary data collected by two 24HDR (n = 18,696), after adjusting for energy intake and estimated energy requirement ratio (EI:EER), $EF_{\geq 50\ kcal} \geq 5.5$ times per day was associated with a 45% higher risk of overweight and obesity [OR (95% CI):1.45 (1.17 - 1.81); $p_{trend} = 0.001$], as well as a 29% higher risk of central obesity [OR (95% CI): 1.29 (1.05 - 1.59); $p_{trend} = 0.03$] compared to the reference group of $EF_{\geq 50\ kcal} \leq 3$ times per day.[14] Also, having a meal frequency (MF) determined by self-report ($MF_{self\text{-}report}$) of 3 and ≥3.5 times per day was associated with a

22% [OR (95% CI): 1.22 (1.03 - 1.46)] and 41% [OR (95% CI): 1.41 (1.10 - 1.82); p_{trend} = 0.003] higher risk of overweight and obesity and a 28% [OR (95% CI): 1.28 (1.09 - 1.49); p_{trend} = 0.004] and 29% [OR (95% CI): 1.29 (1.01 - 1.65); p_{trend} = 0.004] higher risk of central obesity, respectively, when compared to the reference group of $MF_{self\text{-}report} \leq 2$ times per day.[14] Furthermore, having a snack ≥ 3 times per day was associated with a 44% higher risk of overweight and obesity [OR (95% CI): 1.44 (1.11 - 1.85); p_{trend} = 0.02] and 45% higher risk of central obesity [OR (95% CI): 1.45 (1.14 - 1.85); p_{trend} = 0.01] compared to the reference group of ≤ 0.05 snacks per day.[14] Similarly, another cross-sectional study using data from two 24HDR from the USDA Continuing Survey of Food Intake by Individuals (CSFII) in younger (n = 1,792) and older adults (n = 893) found that having a higher EF (> 6 meals/day) was significantly associated with BMI in both the young (β = 1.28 ± 0.44, p = 0.006) and older (β = 2.32 ± 0.75, p = 0.004) adults compared to those reporting ≤ 3 meals and snacks per day.[16] A longitudinal study by Kahleova et al[15] used data from a self-administered calibrated FFQ in combination with an additional follow up questionnaire in order to investigate the relationship between MF and BMI in adults ≥ 30 years from the Seventh-day Adventists Study (n = 50,660). It was found that subjects who had 1and 2 meals per day experienced a decrease in BMI over a year for -0.05 kg/m^2 [95% CI: -0.7, -0.02 kg/m^2] and -0.03 kg/m^2 [-0.04, - 0.02 kg/m^2], respectively, while in subjects who had 4 , 5, and ≥ 6 meals per day, BMI increased for 0.02 kg/m^2 [95% CI: 0.01, 0.03 kg/m^2], 0.02 kg/m^2 [0.01, 0.03 kg/m^2], and 0.04 kg/m^2 [0.02, 0.06 kg/m^2], respectively, when compared to participants who had 3 meals per day.[15] There was a significant linear association between greater number of meals (> 3 per day) and BMI change (p_{trend} < 0.001).[15] All three studies looked at dietary intake at different time periods: 1994 to 1996,[16] 2001 to 2007,[15] and 2003 to 2012.[14] Murakami et al[14] and Kahleova et al[15] both had larger sample sizes compared to Howarth et al[16]. As for dietary assessment methods, Howarth et al and Murakami et al both used two 24HDR[14,16], which is a more accurate dietary assessment method when compared to a FFQ.[14,16] Despite the FFQ being a more unreliable dietary assessment method, it was calibrated against multiple 24HDR.[15] Also, Kahleova et al's[15] study was superior due to its longitudinal study design. In summary, an increased EF may increase overweight/obesity risk in adults.

In contrast, in two cross-sectional studies[17,18] increased EF was associated with a lower prevalence of obesity and a reduction in overweight and obesity risk. Keast et al[17] examined data from NHANES 1999 to 2004 (one to two 24HDR) in adults ≥ 19 years (n = 13,292) and classified adults based on meal skipping and SF. Among meal skippers, adults that snacked throughout the day had lower overweight and obesity prevalence (65.5 ± 0.8%) and risk of overweight and obesity [OR (95% CI): 0.73 (0.61 - 0.88)] compared to adults that did not snack (71.6 ± 1.5%). Among adults that did not skip meals, the prevalence of overweight and obesity was lower in adults that regularly snacked (62.8 ± 1.1%) compared to adults that did not snack throughout the day (66.7 ± 1.2%).[17] Among non-snackers, adults who regularly skipped meals had a higher overweight and obesity prevalence (71.6 ± 1.5%) compared to adults who did not regularly skip meals (66.7 ± 1.2%).[17]

Similarly, in their analysis of the Seasonal Variation of Blood Cholesterol Study including U.S. adults (n = 499) with available dietary data from fifteen 24HDR, Yunsheng et al[18] found that participants with ≥ 4 versus ≤ 3 eating episodes per day were at 45% lower risk of obesity [OR (95% CI) = 0.55 (0.33 - 0.91)]. Though Yunsheng et al's[18] study had higher quality dietary data due to the multiple days of measurement, their sample size was small compared to Keast el al's study[17]. Overall, increasing EF by adding healthy snacks, not skipping meals, or replacing meals with multiple snacks, may reduce the prevalence and risk of overweight and obesity in U.S. adults.

Finally, a study by Barnes et al[29] involving 233 adults in a worksite wellness intervention study (September 2010 to February 2013) using three 24HDRs found no association between SF and BMI. Linear regression models that examined the association between certain snacking behaviors and BMI found that SF was not a significant predictor of BMI (β (SE) = - 0.63 (0.43), $p = 0.151$) in this population. This study had the smallest sample size when compared to the other studies discussed in this section. This implies that this study may have lacked the statistical power to detect a significant relationship between EF and BMI.[29] Overall, more research investigating the relationship between EF and BMI is necessary, since the results are currently inconclusive.

MEAL TIMING AND ENERGY INTAKE

Research is showing that eating later in the day has been associated with increased total caloric intake. Two cross-sectional studies[1-3] used consecutive 7-day food diaries to measure diet found that eating in the evening is associated with an increase in total calories consumed per day. De Castro et al[3] studied the relationship between meal timing and content with TEI in 1,009 adults. Multiple regression analysis was conducted to predict TEI based on time of day (morning, afternoon, and evening) intake of specific foods (e.g., fruit, ice cream, candy, cereal, pastry, sugar, soda, fruit juice, etc.).[3] The majority of foods consumed in the morning had a significant negative association with overall intake (e.g., sugar: $\beta = -0.124$, SE = 0.030, $p < 0.05$; pastry: $\beta = -0.074$, SE = 0.032, $p < 0.05$; fruit juice: $\beta = -0.198$, SE = 0.029, $p < 0.05$). In contrast, the majority of foods consumed in the evening had a significant positive association with overall intake (e.g., sugar: $\beta = 0.100$, SE = 0.025, $p < 0.05$; pastry: $\beta = 0.042$, SE = 0.021, $p < 0.05$; fruit juice: $\beta = 0.122$, SE = 0.024, $p < 0.05$).[3] This analysis indicated that having a higher energy intake in the morning was associated with a lower TEI, while having a higher energy intake in the evening was associated with a higher TEI.[3] Similarly, Baron et al[1] (n = 52) found a significant positive association between TEI and amount of carbohydrates ($r = 0.56$, $p < 0.001$), fats ($r = 0.60$, $p < 0.001$), and protein ($r = 0.68$, $p < 0.001$) consumed after 8 pm and carbohydrates ($r = 0.36$, $p < 0.05$) and protein ($r = 0.43$, $p < 0.05$) consumed within four hours of sleep.[1] Multiple regression analysis controlling for sleep timing, sleep duration, gender, and age found that carbohydrates consumed after 8 pm ($\beta = 0.61$, $p < 0.001$), and carbohydrates ($\beta = 0.29$, $p = 0.046$) and protein ($\beta = 0.33$, $p = 0.02$) consumed four hours before bed were significant predictors of TEI.[1] Using the same study, Reid et al[2] (n = 59) reported a significant association between TEI and timing of the last meal ($r = 0.39$, $p = 0.002$), time between dinner and the last meal ($r = 0.32$, $p = 0.02$) , and time between sleep onset and the last meal ($r = -0.36$, $p = 0.007$). Multivariable regression analysis controlling for age, sleep timing and duration, and sex found that time between dinner and last meal ($\beta = 0.04$, SE = 0.01, $p = 0.007$), time between last meal and sleep onset ($\beta = -0.03$, SE = 0.01, $p = 0.02$), and the timing of the last meal ($\beta = 0.4$, SE = 0.01, $p = 0.001$) were significant predictors of TEI.[2] Both studies indicate that TEI is positively associated with energy intake later in the day.

MEAL TIMING AND BMI

The recent literature has shown that eating later in the day (evening) has been associated with an increase in BMI. Cross-sectional studies by Baron et al[1] and Wang et al[4] both found that eating in the evening was associated with an increase in BMI. Baron et al[1] found that total protein intake ($r = 0.33$, $p < 0.05$), carbohydrates ($r = 0.29$, $p < 0.05$), protein ($r = 0.39$, $p < 0.01$), and fat intake ($r = 0.32$, $p < 0.05$) after 8 pm and protein consumed within four hours of sleep ($r = 0.37$, $p < 0.05$) were associated with a higher BMI. It was also found that consuming a greater amount of fat after 8 pm was associated with a higher BMI ($r = 0.30$, $p < 0.05$).[1] Multiple regression analysis controlling for sleep timing, sleep duration, sex, and age found that consuming protein four hours before sleep was a significant predictor of BMI ($\beta = 0.31$, $p = 0.03$).[1] Similarly, a study by Wang et al[4] investigated the relationship between energy intake during different times of day (morning, midday, and evening) and BMI in a sample of adults ($n = 239$) from Los Angeles, CA with the use of three 24HDRs. They reported a weak positive association between evening (5:00 pm -12:00 am) energy intake and BMI ($r = 0.20$, $p = 0.05$).[4] Moreover, subjects who consumed ≥ 33% of their total energy intake in the evening were twice as likely to be overweight or obese compared to the subjects who had < 33% of their total daily energy intake in the evening [OR (95% CI) = 2.00 (1.03-3.89)].[4] Limitations include that both Baron et al[1] and Wang et al[4] had small sample sizes. In summary, the current literature indicates that BMI is positively associated with eating later in the day.

NIGHT EATING AND WEIGHT GAIN MECHANISM

Eating later in the day may lead to weight gain due to a disruption in circadian rhythms,[63] reduced diet induced thermogenesis (DIT), which is known to be lower in the evening, [64] and reduced glucose utilization[65] and energy expenditure when asleep,[66] with sleep deprivation potentially playing a role in this mechanism. Circadian rhythms are controlled by biological clocks, and are changes that occur in the body according to a 24 hr cycle: eating habits, digestion, hormone release, and sleep and wake cycles.[63] These changes are signaled by environmental or hormonal cues like light and dark cycles.[63] Both animal[67,68] and human studies [1,4,69,70] have shown that eating outside of one's circadian rhythms, for example, at night time in humans, is associated with weight gain and adverse metabolic outcomes. There is evidence to show that DIT was lower after a meal consumed in the evening (8:00 pm), compared to the same meal consumed in the morning (8:00 am),[64] which may be due to reduced gastric emptying found at night time.[71] During sleep, energy expenditure decreases by approximately 15%.[72] During the early sleep phase in particular, there is a decrease in glucose utilization, due to decreased insulin sensitivity of peripheral tissues, which is probably hormone induced, and/or decreased brain glucose metabolism occurring during that sleep stage,[65] potentially promoting weight gain. Sleep deprivation may also play a role in the night eating weight gain mechanism. Research has found that sleep deprivation leads to dysregulation of the hunger hormones.[73] Normally, leptin and ghrelin have been found to increase during sleep, with a decrease in ghrelin levels throughout the night.[73] With sleep deprivation, there is a decrease in leptin,[73] the fullness hormone, and an increase in ghrelin, the hunger hormone[73,74]. It has also been found that with inadequate sleep comes an increase in carbohydrate food cravings, such as desserts and salty snacks.[73] Therefore, dysregulated hunger hormones caused by abnormal sleeping patterns may result in over eating of high calorie and high sugar foods during the night period. In conclusion, disrupted circadian rhythms, reduced DIT, reduced glucose utilization and energy expenditure while sleeping, and inadequate sleep may be contributing to the rise of obesity and chronic disease in the U.S. population.

CONCLUSION

In summary, both added sugars intake and eating patterns have been found to be associated with TEI and BMI. Added sugars have been positively associated with increased weight gain, but whether that relationship is due to increased TEI[40,41] or the effects of the added sugar itself[42,43] are unknown. There is a positive relationship between EF and TEI;[13,61,62] however, the relationship between EF and BMI is inconclusive.[14-18,29] There also is a positive relationship between later meal timing and TEI,[1-3] as well as later meal timing and BMI.[1,4] With that being said, a majority of the current research in this area has relied on few days of self-reported dietary intake, which can lead to under-reporting and inaccurate dietary intake estimates. Current research has also utilized many different definitions for meals, snacks, and added sugars. Future research should focus on finding standardized definitions for meals, snacks, and added sugars and/or clearly defining the definitions they choose to use. Research evaluating current patterns of added sugars intake in the U.S. are lacking. Further, there has never been a study evaluating patterns of added sugars consumption, and its relation to energy intake and BMI, dependent and independent of TEI. In this 15-day highly controlled feeding study with available information on meal timing we will describe the patterns of added sugars consumption in healthy adults age 18-70 years, and study the association between dietary sugars, eating patterns, TEI, and BMI. The controlled study design will allow us to overcome the limitations of previous research, since we will rely on ‘true’ dietary intake, and have information on meal timing and the composition of meals over a 15-day period.

CHAPTER 3

METHODS

PARTICIPANTS AND STUDY DESIGN

Study Participants

Study participants included 40 healthy non-smoking adults (18-70 years) with a BMI <35 kg/m^2 living in the Phoenix area recruited from October 2016 to March 2018. The participants were part of a larger controlled feeding study, the Sugars Bio study (March 2016-June 2019), conducted to develop dietary biomarkers of sugars intake. People were considered ineligible to participate if they had a fasting blood glucose >100 mg/dL or HbA1c ≥5.7%, have been diagnosed with DM (Type I or Type II), kidney disease, bladder incontinence, underwent a dietary restriction due to a medical condition or weight change, participated in a diet research study over the last four months, had an allergy to sunscreen, amino benzoate potassium (POTABA), or para-amino benzoic acid (PABA), or, for women, if they were currently breastfeeding or pregnant.

Study Recruitment

Recruitment started in February of 2016 and was geared towards Arizona State University (ASU) students, staff, and faculty as well as businesses and buildings around the Arizona Biomedical Collaborative building at the downtown Phoenix campus. Recruitment strategies included word of mouth, the Sugars Bio website (http://sugarsbio.org/), the Sugars Bio Facebook page and advertisements (https://www.facebook.com/asusugarsbio/), email blasts, and posters displayed around campus, local coffee shops, churches, senior centers, and businesses (See Appendix A for study poster). People who expressed interest from these advertisements were emailed the Study Information Sheet (See Appendix B for Study Information Sheet). If they were still interested, they were asked to fill out the Screening Questionnaire (See Appendix C for the Screening Questionnaire). The Screening Questionnaire took ten minutes to complete and it asked questions related to the eligibility criteria to see if they would be eligible for the study. Then, the Project Coordinator contacted the eligible participants to schedule a screening visit. All participants in the study provided written informed consent during their screening visit (See Appendix D for Consent form). At the screening visit, the Project Coordinator went over the consent form, detailing the purpose of the study, possible risks and benefits, and an overview of the study and timeline. Also, during the screening visit, participant's height and weight were measured in order to calculate BMI, and blood was collected to measure fasting blood glucose and HbA1c. The blood samples were sent to a certified lab for analysis. Once eligibility was confirmed, the participant was scheduled for a baseline visit. The study was approved by the Institutional Review Board (IRB) of ASU (See Appendix E for ASU IRB Approval).

Sample Selection Description

From March 2016 to January 2018, 149 people were screened for the Sugars Bio study. Out of 149, 89 were eligible and 60 were ineligible due to having a fasting blood glucose >100 mg/dL (n=8), a fasting blood glucose > 100 mg/dL and HbA1c > 5.7% (n = 3), a fasting blood glucose > 100 mg/dL and BMI > 35 kg/m^2 (n = 1), HbA1c ≥ 5.7% (n = 21), HbA1c > 5.7% and thyroid medication use (n = 1), BMI > 35 kg/m^2 (n = 3), a medication interaction (n = 7), dietary restrictions (n = 2), thyroid issues (n = 1), refusal to stop supplement use (n = 3), participation in another study (n = 1), no show (n = 1), couldn't draw blood (n = 1), intermittent fasting (n = 1), weight loss diet (n = 4), recent smoker (n = 1) and did not complete blood work (n = 1). Out of the 89 people that were eligible, 60 were scheduled based off of their availability, 4 were unwilling to participate given the strict study protocol, 15 had expired blood results, 7 were no longer interested, and 3 were scheduled for later enrollment. The first 19 participants were not included in our data analysis because they did not have reliable data on meal composition or timing. Starting with participant 20, an update to our study protocol and study materials were implemented, which resulted in more reliable data on meal content and timing in the following 40 participants that were used in our study.

Study Design

This study was a secondary analysis of a 15-day, highly controlled feeding study where participants consumed their normal diet (See Appendix F for Study Flow Chart). At the baseline visit, participants were administered a Baseline Questionnaire, which asked questions about demographics, medical history, and lifestyle (See Appendix G for baseline questionnaire). Then, each participant was trained on how to keep a food diary by the Research Chef, so their normal diet could be assessed and replicated during the feeding period. After the training, participants completed two consecutive 7-day food diaries, recording all foods and beverages consumed, portion sizes, brands, and recipes used. The USDA Food Models for Estimating Portions was utilized by the participants to estimate the portion sizes of consumed foods and beverages (See Appendix H for The

USDA Food Models for Estimating Portions). After the completion of each 7-day food diary, the participant met with the Research Chef to go through the items recorded and provide more details if necessary. Then, the Research Chef had one week to make the menu plans and purchase the food and drinks needed for the feeding group. During the 15-day feeding period, participants were provided with all of their food by the metabolic kitchen and were not allowed to eat anything outside of the food provided to them or throw away any leftovers. The participants were also instructed to track their meal and snack content and times each day. The participants were weighed before breakfast or lunch every week day and consumed as much of the food and drinks provided by the metabolic kitchen that they wanted. Monday through Friday one meal was eaten at the metabolic kitchen (usually breakfast), and the rest was packed in a cooler so they could take it with them and go through their normal daily activities. On Friday the participant received all meals for the weekend. The foods and drinks leftover were brought back to the metabolic kitchen the next day or after the weekend, and carefully weighed so the amount of food consumed could be calculated. Daily feeding data were then entered into the NDSR for analysis.[70] The participants also filled out a Meal Checklist (See Appendix I for Meal Checklist) daily in relation to the Menu Plan (See Appendix J for Menu Plan). The Menu Plan listed out each food and beverage provided for each meal and snack. The Meal Checklists were reviewed by the Project Coordinator and the Research Chef after every feeding day during the weekdays and on Monday after the weekends in order to make sure that the participant complied with the feeding protocol and that the composition and timing of each meal and snack were accounted for and documented correctly. Two participants were recruited every three weeks per feeding group. Rolling recruitment was implemented due to the intensity of the study, which allowed having only two participants at a time for the feeding component of the study.

PROTOCOL PROCEDURES

Anthropometrics

Body height and weight were measured at screening. Throughout the feeding period, body weight was taken every Monday-Friday before breakfast or lunch, to make sure that their weight remained stable. Height and weight were measured using a digital measuring station with wireless transmission (SECA 284). Participants wore light clothing, emptied their pockets, and wore no shoes when weight measurements were taken. For height the participant was instructed to step back onto the measuring station, their heels touching the back of the scale, head and back straight, weight distributed evenly on both legs, arms straight at their sides, and head looking straight ahead in alignment with the Frankfurt plane. Next the headpiece was lowered, making sure that it rested firmly on the head. Then the Frankfurt measure was pulled out of the head slide to make sure the head was in the right position before taking the measurement. Last the participant was asked to stand straight and take a breath, and the measurement was read off of the digital measuring station display. Both height and weight measurements were taken twice, and the average was calculated for both measurements and used in the BMI calculation. Body Mass Index (BMI) was calculated using the equation body weight (kg)/ height (m^2).

Meal Planning Protocol

Each participant's normal diet was assessed by two 7-day food diaries and replicated by a trained Research Chef during the 15-day feeding study. An account on plantoeat.com was used to keep track of recipes (amount of servings per recipe), create the feeding calendar, and to create a shopping list. Most foods were purchased online from Safeway. Brands found in NDSR were given priority. Specialty food items were purchased from Sprouts, Whole Foods, Trader Joe's, or Lee Lee's Market. Items that could be bought in bulk were purchased through Shamrock Foods. Before receiving orders, the food was rotated and the shelves in the pantry, refrigerator, and freezer were cleaned and sanitized in order to reduce food waste and prevent food-borne illness. When food orders arrived, all items were inspected for damage, dents, mold, etc. and bulk items were vacuum sealed and stored appropriately.

Feeding Protocol

<u>Meal Preparation Protocol</u>

All foods, drinks, condiments, and sweeteners were prepared or supplied by the metabolic kitchen for the feeding study. All foods and drinks were weighed to the nearest gram and recorded in the Food Log Book (See Appendix K for Food Log Book) before being packed in labeled color-coded to-go containers, cooled, and placed in the refrigerator. Participants were given approximately 1.5 times the amount of food they consumed during their food diary period. On the weekends, the participants were given an extra snack bag, which consisted of snack foods and drinks that they normally would consume. The brand name and amount of sugar per serving was recorded in the notes section of the Food Log Book so we could make sure to use a product with the same or comparable amount of sugar content in NDSR. If food was prepared by a recipe, all the ingredients, weight of the food before cooking, and weight after cooking were measured to the nearest gram and recorded in the Food Log book under the recipe section. When the participant came to pick up their meals, the labeled color-coded containers were placed in a cooler with ice packs for each participant and checked off the "packed in the cooler" column in the Food Log Book to ensure that each item was packed and given to the participant. Participants ate one supervised meal (breakfast or lunch) per day during the weekdays at the metabolic kitchen and took the rest of the meals for the day (lunch, dinner, and snacks) with them to-go in a cooler with ice packs. On Fridays the participant collected all their meals for the weekend to-go in a cooler with ice packs.

Processing Returned Meals Protocol

The participant could eat as much of the food prepared for them as they wanted, but they had to return all the leftovers the next day, or on Monday if it was over the weekend, so the amount of food consumed could be weighed and amounts estimated. Returned meals were processed by zeroing out the scale with a clean, identical storage container and then weighing the storage container with the returned meal, snack, or beverage inside. Returned weights were recorded in the Food Log Book. Then the food consumed was calculated by subtracting the weight from the food given from the weight of the food returned, recorded in the Food Log Book, and checked by the Research Chef or another kitchen staff member. Storage containers were then washed and the cooler and ice packs were sanitized before use.

Meal Checklist Training and Review Protocol

To check compliance with the feeding protocol, participants were asked to complete a meal checklist daily during the 15-d feeding period. For each meal or snack, participants were instructed to mark whether they consumed the meal (breakfast, lunch, dinner) or snack (pre-breakfast, morning, afternoon, evening, and late night) and the time they consumed the meal or snack, using the information from the Menu Plan. If they changed their meals (e.g., combined food from a meal and/or snack or didn't eat an item provided) they were instructed to record that change to the specific meal or snack in the notes section on the meal checklist. While participants were allowed to consume black coffee, black tea, or alcohol (beer, wine, hard liquor) outside of what was given to them, they were asked to keep the intake consistent and record the brand name and amount consumed in ounces. If outside food was accidently consumed, they were instructed to record the food and approximate amount eaten, and bring the food wrapping, if available. The Meal Checklist was reviewed by the Project Coordinator and the Research Chef after every feeding day Monday through Friday and on Monday for the feeding days over the weekend. The Project Coordinator and the Research Chef worked together to review which meals and snacks were consumed and at what times. This review is where questions were asked if there was missing information in the Meal Checklist or if the participant ate the menu items out of order.

Processing of Dietary Data

Dietary intake data were collected and analyzed using Nutrition Data System for Research software (version 2017) developed by the Nutrition Coordinating Center (NCC), University of Minnesota, Minneapolis, MN. This database has complete nutrient profile for thousands of different types of foods.[75] The reviewed food intake data from the Food Log Book was entered into NDSR. The food code was identified based on the brand used. If the brand was not available we first tried to find a comparable product similar in nutrient and sugar content. If a comparable product couldn't be found, we had the NDSR team add the item into the database. Recipes were entered into NDSR by using ingredients, weights, cooking methods, and moisture loss after cooking, where appropriate, and entered as a recipe code. Total energy, total sugars, added sugars, sucrose, fructose, fat, protein, carbohydrate intakes were then generated.

Meal coding

Meal type was identified using specific Meal Criteria (See Appendix L for Meal criteria), which involved the combination of participant-identified meal type, time of day, and meal content. EO's that were eaten within fifteen minutes of each other were combined as one EO. A **main meal** was identified as an EO identified by the participant as breakfast, lunch or dinner between the following times (Breakfast: 5:00 am-10:59 am, Lunch: 11:00 am-3:59 pm, Dinner: 4:00 pm-12:00 am) or an EO identified by the participant as snack while the EO was composed of meal foods and meal consisted of 3 or more food groups and provided a similar amount of calories to a typical meal for the participant. If two main meals were identified during the same time period, based on meal content, one would be allocated as a meal and the other as a snack, if appropriate. If not (i.e., if similar in calories, composed of meal foods, and meal consisted of 3 or more food groups) they would be coded as two meals. A **snack** was an EO identified by the participant as snack between the following times (5:00 am-10:59 am, 11:00 am-3:59 pm, and 4:00 pm-12:00 am) or an EO that occurred from 12:00 am-5:00 am or an EO composed of snack foods only or an EO that consisted of 1-2 food items or an EO that consisted of leftovers from a consumed meal or an EO that consisted of snack foods eaten alone but given as part of a meal. However, if two or more snacks and no main meal were identified by the participant between any of defined times; the EO's were allocated as snacks, if appropriate based on content. Beverages that were consumed alone, not as part of a meal or snack, were identified as **beverage only** occasions.

Physical Activity Assessment

Participants' physical activity was assessed using a Physical Activity Log (See Appendix M for Physical Activity Log Book), which has been previously validated.[76] The participant logged every activity that they participated in longer than ten minutes throughout the day from six activity domains (home, transportation, work, conditioning, sports, and leisure activities). They were asked to record the time that they started the activity and minutes or hours the activity was performed. If the participant did an activity that wasn't listed in the log, they could write it in the "other" section. The "Compendium of Physical Activities" (https://sites.google.com/site/compendiumofphysicalactivities/home) was used to assign Metabolic Equivalent Values (METs) to each of the activities from the log and to any 'other' activities noted by participants. *Total METs/h* was estimated for each domain by calculating the sum of individual activity MET hours, which is done by multiplying the number of hours that the activity was performed by the MET value assigned for that activity. Day totals were calculated for METs/h by taking the sum of Total MET hours for all domains. Day totals for *total active METs/h* were estimated by calculating the total MET hours subtracted by total sedentary MET hours (sum of MET hours for sedentary activities) and total standing MET hours (sum of MET hours for activities done while standing). The 15-day mean of active METs/h were used in our analysis.

STATISTICAL ANALYSIS

The dependent variables in the analysis were TEI and BMI. The independent categorical variables included ethnicity, education level, annual family income, and marital status. The independent continuous variables included age (years), BMI, active MET hours, Total EO frequency, Total EO frequency (no beverages only), energy intake (kcal/d) by meal type (breakfast, lunch, dinner, snacks, beverages only) and by time of day (**Morning**: 5:00 am - 10:59 am, **Afternoon**: 11:00 am - 3:59 pm, **Evening**: 4:00 pm - 7:59 pm, and **Night**: 8:00 pm - 4:59 am), % energy by meal type [for example, % energy from breakfast = breakfast energy intake (kcal) x 100/ TEI (kcal)] and time of day [for example, % energy from the morning = morning energy intake (kcal) x 100/TEI (kcal)], % energy from added sugars [Added sugars (g) x 4 kcal x 100/TEI (kcal)], % energy from added sugars by meal type [for example, % energy from added sugars from breakfast = Added sugars (g) from breakfast x 4 kcal x 100/TEI (kcal)] and time of day [for example, % energy from added sugars from the morning = Added sugars (g) from the morning x 4 kcal x 100/TEI (kcal)], % meal energy from added sugars [for example, % breakfast energy from added sugars = Added sugars (g) from breakfast x 4 kcal x 100/Breakfast energy intake (kcal)] and % time of day energy from added sugars intake [for example, % morning energy from added sugars = Added sugars from the morning (g) x 4 kcal x 100/ Morning energy intake (kcal)], and % added sugars by meal type [for example, % added sugars from breakfast = Added sugars intake (g) from breakfast/Added sugars (g/d) x 100] and time of day [for example, % added sugars from the morning = Added sugars intake (g) in the morning/Added sugars (g/d) x 100]. The continuous variables came from the meal level file, which was broken down into the day level file, time of day level file, and the meal name file. These files included the sum of all continuous variables that had multiple entries by day, time of day, or meal name. From these files the participant level mean file was created, which contained the 15-d mean for each continuous variable per participant. All data were checked for normality and transformed using sqrt, log10, or inverse transformations (See Appendix N for Variable Distribution and Transformation Table). Skewed variables with zero values were either transformed by sqrt or not transformed at all, since log10 and inverse transformations resulted in missed values. Three variables had a skewed distribution and could not be transformed: % energy from added sugars from beverages only, % beverages only energy from added sugars, and % added sugars from beverages only. Nonparametric tests were used in the analyses that included those three variables.

Demographic characteristics and dietary data were reported by gender and tertiles of energy from added sugars intake (%). Categorical variables were expressed as n (%) and continuous variables were expressed as median (interquartile range). For categorical variables, chi square tests were run to compare observed frequencies between men and women and between tertiles of energy from added sugars intake (%). For continuous variables, independent t-tests were run to compare mean values between men and women, and the t-value was reported. One-way ANOVA was run to compare mean values between tertiles of energy from added sugars intake (%), and the F value was reported. Pearson correlation was used to test the correlation between all tested variables, normally distributed or transformed. If the data were skewed and could not be transformed, Spearman correlation with non-transformed variables was used. The r values were reported for correlation analyses.

Independent t-test was used to compare energy intake (kcal/d), % energy and % added sugars by meal type (breakfast, lunch, dinner, snacks, and beverages only) and time of day (morning, afternoon, evening, and night), and % meal energy from added sugars and % time of day energy from added sugars between males and females. The Mann-Whitney U test was used as a non-parametric alternative when variables had a skewed distribution, and the Z values were reported.

Paired t-test was used to compare pre and post study weights in order to check for energy balance in the participants during the feeding study.

For men and women, all variables were checked for normality and transformed, using sqrt, log10, inverse, or reflect sqrt transformations (See Appendix O for the Variable Distribution and Transformation Table for males and Appendix P for the Variable Distribution and Transformation Table for females). For men, the variable % energy intake from dinner, had a skewed distribution and could not be transformed. For women, the variables, % added sugars from beverages only and % beverages only energy from added sugars had a skewed distribution and could not be transformed. For either sex, to test whether there was a significant difference between the energy intake (kcal/d), percent energy from total energy, and the percent added sugars from total added sugars across meal types and times of day, as well as % meal energy from added sugars across meal types and % time of day energy from added sugars across times of day, and where that difference lied, one-way repeated measures ANOVA with post hoc test were used. The F value and p-values were reported. If the data were skewed, the non-parametric equivalent, the Friedman test and the Wilcoxon Signed Rank Test with Bonferroni correction were used to control for multiple comparisons. The Chi-Square value and Z values were reported. Bonferroni correction was calculated by dividing the critical p value ($p < 0.05$) by the number of comparisons for all meal types ($n = 10$). After applying Bonferroni correction, significance was set at $p < 0.005$, respectively.

Multiple linear regression models were analyzed to determine whether % added sugars or % energy intake from different meal types or times of day were significant predictors of TEI or BMI. In total, six multiple linear regression models were conducted. All meal types (% energy or % added sugars) or times of day (% energy or % added sugars) were included in the exploratory models all at once and excluded if they were not significant predictors of TEI or BMI, or if they didn't add to the predictability of the model. However, it should be noted that the % added sugars from beverages only was not included in the model regressing TEI or BMI on % added sugars by meal type, as the variable did not include sugars from total beverages, but only beverages consumed outside of meals. All models included age, sex, and total EO frequency (with or without beverages only) in order to see if they increased the predictability of the model and were removed if they did not. The linear regression models that were fitted to predict BMI controlled for age, sex, and total EO frequency, in addition to physical activity (active MET hours). We built models with and without TEI to see if the effect of % added sugars or % energy intake by meal types or times of day on BMI was dependent or independent of TEI. The β coefficient, standard error, and adjusted R^2 values were reported. The statistical significance was set at $p < 0.05$. The Statistical Package for Social Sciences (SPSS) was used for all statistical analysis.

CHAPTER 4

RESULTS

Participants

In total, 15 men (37.5%) and 25 women (62.5%) living in the Phoenix Metro Area were included in data analysis. The mean age of participants was 40.9 ± 13.5 years. The mean BMI was 27.0 ± 4.0 kg/m^2, with 72.5% of the participants being classified as overweight or obese (**Table 1**). The study population was predominantly white (82.5%). The mean active MET-hours/day was 11.3 ± 5.1. There was no significant difference between pre and post study weights, indicating that the participants were kept at energy balance during the feeding period ($t = 0.35$; $p = 0.748$).

The 15-d median % energy from added sugars was 9.7 ± 5.4%, and it was similar between men and women ($t = 0.60$, $p = 0.555$). The number of EO's in this population was 5.3 ± 1.3 per day. On average, participants had 2.9 ± 0.2 meals, 1.9 ± 0.8 snacks, and 0.4 ± 0.5 beverage only occasions per day. While the median number of meals and beverages only per day were similar between men and women (meals: $t = -1.57$, $p = 0.126$; beverages only: $t = 1.14$, $p = 0.262$), women had a significantly higher number of snacks than men ($t = -2.58$, $p = 0.014$). All demographic characteristics and dietary variables were similar across tertiles of % energy from added sugars (**Table 3** and **Table 4**).

Table 1. Demographic Characteristics by Sex from Healthy Participants in a Highly Controlled 15-day Feeding Study Living in the Phoenix Metro Area (n = 40)[1]

Demographic characteristics	Men (n = 15)	Women (n = 25)	All (n = 40)	p-value[2]
Age categories				
18-34 years	8 (53.3)	8 (32.0)	16 (40.0)	0.597
35-44 years	2 (13.3)	4 (16.0)	6 (15.0)	
45-54 years	3 (20.0)	7 (28.0)	10 (25.0)	
55-70 years	2 (13.3)	6 (24.0)	8 (20.0)	
BMI categories[3]				
Normal weight	4 (26.7)	7 (28.0)	11 (27.5)	0.939
Overweight	8 (53.3)	12 (48.0)	20 (50.0)	
Obese	3 (20.0)	6 (24.0)	9 (22.5)	
Ethnicity				
White	11 (73.3)	22 (88.0)	33 (82.5)	0.392
Other	4 (26.7)	3 (12.0)	7 (17.5)	
Education level				
Some college or less	9 (60.0)	5 (20.0)	14 (35.0)	0.027
Bachelors	4 (26.7)	9 (36.0)	13 (32.5)	
Graduate Degree	2 (13.3)	11 (44.0)	13 (32.5)	
Annual family income				
<$15,000-$24,999	2 (13.3)	3 (12.0)	5 (12.5)	0.608
$25,000-$64,999	4 (26.7)	8 (32.0)	12 (30.0)	
$65,000-$104,999	4 (26.7)	10 (40.0)	14 (35.0)	
>$105,000	5 (33.3)	4 (16.0)	9 (22.5)	
Marital status				
Single or Divorced	6 (40.0)	12 (48.0)	18 (45.0)	0.747
Married	9 (60.0)	13 (52.0)	22 (55.0)	

[1] All values are n (%).
[2] Chi square test was run to compare observed frequencies between men and women.
[3] Normal weight: BMI = 18.5 - 24.9 kg/m^2; Overweight: BMI = 25 - 29.9 kg/m^2; Obese: BMI = 30 - 35 kg/m^2

Table 2. Dietary Data[1] by Sex from Healthy Participants in a Highly Controlled 15-day Feeding Study Living in the Phoenix Metro Area (n = 40)[2]

Dietary variables	Men (n = 15)	Women (n = 25)	All (n = 40)	p-value[3]
Total EO frequency (n/d)	5.1 (1.5)	5.4 (1.3)	5.3 (1.3)	0.078
Meal frequency (n/d)	2.9 (0.2)	2.9 (0.3)	2.9 (0.2)	0.126
Snack frequency (n/d)	1.5 (1.2)	2.0 (0.9)	1.9 (0.8)	0.014
Beverages only frequency (n/d)	0.5 (0.9)	0.4 (0.5)	0.4 (0.5)	0.262
Energy intake (kcal/d)	3016.3 (549.7)	2373.5 (484.7)	2715.3 (712.4)	< 0.001
Energy from added sugars (%)	9.6 (7.0)	9.9 (4.1)	9.7 (5.4)	0.555

EO: eating occasion.
[1] Based on 15-days of diet
[2] Values are median (interquartile range).
[3] Independent t-test was run to compare mean values between men and women.

Table 3. Demographic Characteristics from Healthy Participants in a Highly Controlled 15-day Feeding Study Living in the Phoenix Metro Area by Tertiles of Energy Intake from Added Sugars (%) Intake (n = 40)[1]

Demographic characteristics	Energy Intake from Added Sugars (%)			p-value[2]
	T1 (3.25 - 8.45)	T2 (8.46 - 11.60)	T3 (11.61 - 18.81)	
Gender				0.220
Male	5 (38.5)	3 (21.4)	7 (53.8)	
Female	8 (61.5)	11 (78.6)	6 (46.2)	
Age categories				
18-34 years	7 (53.8)	6 (42.9)	3 (23.1)	0.722
35-44 years	2 (15.4)	1 (7.1)	3 (23.1)	
45-54 years	2 (15.4)	4 (28.6)	4 (30.8)	
55-70 years	2 (15.4)	3 (21.4)	3 (23.1)	
BMI categories[3]				
Normal weight	3 (23.1)	4 (28.6)	4 (30.8)	0.994
Overweight	7 (53.8)	7 (50.0)	6 (46.2)	
Obese	3 (23.1)	3 (21.4)	3 (23.1)	
Ethnicity				
White	12 (92.3)	11 (78.6)	10 (76.9)	0.523
Other	1 (7.7)	3 (21.4)	3 (23.1)	
Education level				
Some college or less	3 (23.1)	5 (35.7)	6 (46.2)	0.781
Bachelor's degree	5 (38.5)	4 (28.6)	4 (30.8)	
Graduate degree	5 (38.5)	5 (35.7)	3 (23.1)	
Annual family income				
<$15,000-$24,999	0 (0)	3 (21.4)	2 (15.4)	0.239
$25,000-$64,999	6 (46.2)	5 (35.7)	1 (7.7)	
$65,000-$104,999	5 (38.5)	3 (21.4)	6 (46.2)	
>$105,000	2 (15.4)	3 (21.4)	4 (30.8)	
Marital status				
Single or Divorced	5 (38.5)	8 (57.1)	5 (38.5)	0.526
Married	8 (61.5)	6 (42.9)	8 (61.5)	

[1] All variables are n (%)
[2] Chi square test was run to compare observed frequencies between tertiles.
[3] Normal weight: BMI = 18.5 - 24.9 kg/m^2; Overweight: BMI = 25 - 29.9 kg/m^2; Obese: BMI = 30 - 35 kg/m^2

Table 4. Dietary Data[1] from Healthy Participants in a Highly Controlled 15-day Feeding Study Living in the Phoenix Metro Area by Tertiles of Energy Intake from Added Sugars (%) Intake (n = 40)[2]

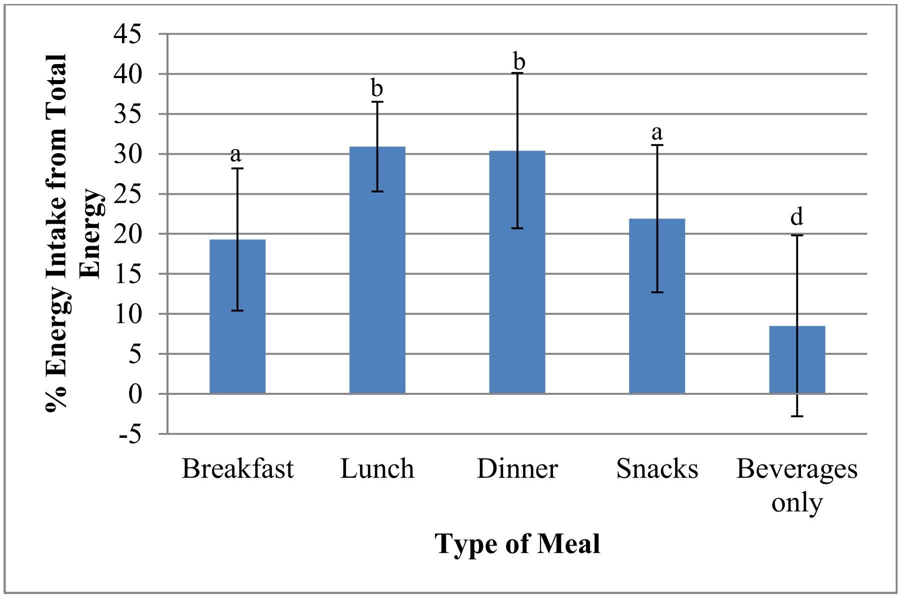
Dietary variables	Energy Intake from Added Sugars (%, range)			p-value[3]
	T1 (3.25 - 8.45)	T2 (8.46 - 11.60)	T3 (11.61 - 18.81)	
Total EO frequency (n)	5.8 (1.5)	5.3 (1.1)	5.1 (0.8)	0.115
Meal frequency (n)	2.9 (0.3)	2.9 (0.4)	2.9 (0.2)	0.973
Snack frequency (n)	2.3 (1.4)	1.9 (0.8)	1.7 (1.0)	0.125
Beverages only frequency (n)	0.7 (0.8)	0.5 (0.5)	0.3 (0.4)	0.618
Energy intake (kcal/d)	2856.8 (851.6)	2707.6 (642.7)	2721.4 (641.7)	0.848

EO: eating occasion
[1] Based on 15-days of diet
[2] Values are median (interquartile range).
[3] One-way ANOVA was run to compare mean values between tertiles.

Energy intake by meal type

The % energy from breakfast ($t = 1.05$, $p = 0.302$), lunch ($t = 1.43$, $p = 0.160$), dinner ($t = 1.28$, $p = 0.210$), snacks ($t = -1.25$, $p = 0.219$), and beverages only ($t = 0.93$, $p = 0.360$) were similar between men and women. The percent energy between meals differed in both men ($\chi^2 = 46.8$, $p < 0.001$) (**Figure 1A**) and women [$F_{1.5, 35.2} = 103.9$, $p < 0.001$] (**Figure 1B**). Yet, in men, similar % energy came from breakfast and snacks ($p = 0.691$) and lunch and dinner ($p = 0.069$), while in women, % energy intake was similar between breakfast and beverages only ($p = 0.112$). The highest contribution to daily energy came from lunch (31% in men) and dinner (30% in men and women), while the lowest contribution came from beverages only (9% in men and 4% in women).

A: Males[1]



B: Females[2]

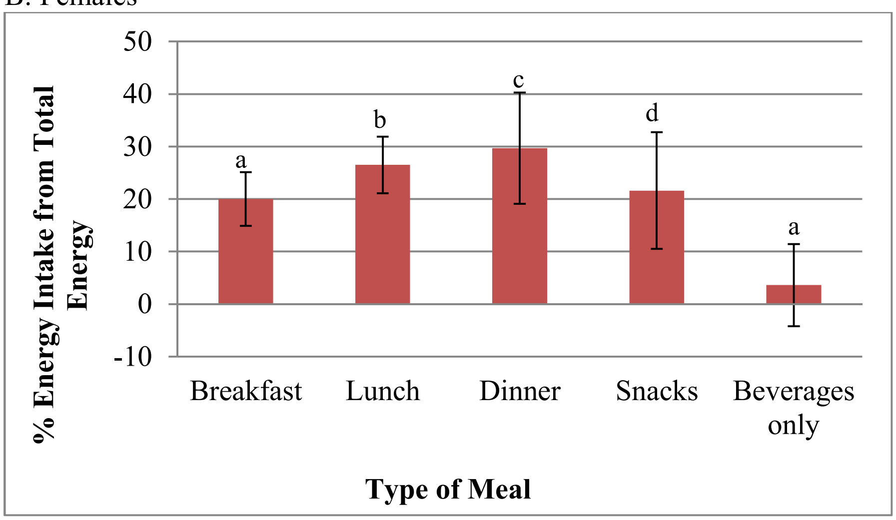


Figure 1: % 15-day Mean Energy Intake by Meal Type from Healthy (A) Male (n=15) and (B) Female (n=25) Participants in a Highly Controlled 15-day Feeding Study Living in the Phoenix Metro Area

[1] Friedman Test [$\chi^2 = 46.8$, $p < 0.001$] and Wilcoxon Signed Rank Test with Bonferroni correction was run for to test whether there was a significant difference in % energy between meals. A different letter indicates a statistically significant difference ($p < 0.005$). Data are expressed as % Median ± Interquartile Range.

[2] Repeated Measures ANOVA [$F_{1.5, 35.2} = 103.9$, $p < 0.001$] with post hoc tests was run to test whether there was a significant difference in % energy between meals. A different letter indicates a statistically significant difference ($p < 0.05$). Data are expressed as % Median ± Interquartile Range.

Energy intake (kcal/d) was significantly higher in men than in women for breakfast (t = 3.80, p = 0.001), lunch (t = 3.81, p < 0.001), and dinner (t = 3.50, p = 0.001), however, it was similar for snacks ($t = 0.81$, $p = 0.420$) and beverages only ($t = 1.39$, $p = 0.172$) (**Table 5**). Energy intake (kcal/d) significantly differed across meals in both men [$F_{1.1, 14.9} = 159.5$, $p < 0.001$] and women [$F_{1.5, 35.2} = 103.9$, $p < 0.001$]. Overall, the highest energy contribution came from dinner (1019 kcal/d in men and 720 kcal/d in women) and the lowest came from beverages only (210 kcal/d in men and 107 kcal/d in women). Common beverage only occasions in our population included coffee, alcohol, and tea.

Table 5. 15-day Mean Energy and Added Sugars Intake by Meal Type[1] and Sex from Healthy Participants in a Highly Controlled 15-day Feeding Study Living in the Phoenix Metro Area (n = 40)[2-3]

Meal type	Energy intake (kcal/d)		Meal energy from added sugars (%)	
	Men (n = 15)	Women (n = 25)	Men (n = 15)	Women (n = 25)
Breakfast	587.2 (204.8)[a]	512.2 (126.5)[a]	8.5 (10.1)[a,c]	8.7 (12.4)[a]
Lunch	1002.9 (293.6)[b]	652.4 (200.3)[b]	7.7 (11.5)[a]	6.2 (6.2)[a,b]
Dinner	1019.2 (432.5)[c]	720.3 (310.7)[c]	3.9 (6.4)[c]	4.0 (3.4)[b]
Snacks	703.6 (288.9)[d]	548.8 (170.1)[d]	20.1 (14.0)[b]	18.3 (5.7)[c]
Beverages only	210.7 (320.3)[e]	107.2 (222.4)[e]	19.7 (36.0)[a,b,c]	8.0 (29.5)[a,b,c]

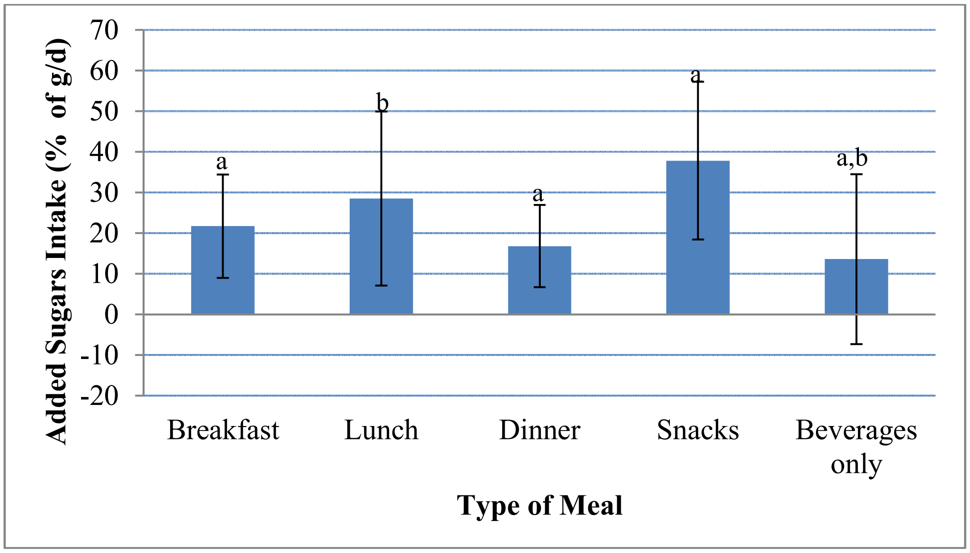
[1] See Appendix L for meal type definitions
[2] Values are median (interquartile range).
[3] Repeated measures ANOVA with post hoc tests or Friedman Test and Wilcoxon Signed Rank test with Bonferroni correction was run to test whether there was a significant difference in energy intake or % meal energy from added sugars between meals (comparison by column). Different letter indicates a statistically significant difference ($p < 0.05$ for Repeated measures ANOVA with post hoc tests or $p < 0.005$ for Friedman Test and Wilcoxon Signed Rank test with Bonferroni correction, respectively).

Added sugars intake by meal type

The % meal energy from added sugars was similar in men and women for breakfast (Z = -0.55, p = 0.586), lunch (Z = -1.16, p = 0.246), dinner (Z = -0.18, p = 0.856), snacks (Z = -0.91, p = 0.364), and beverages only (Z = -0.89, p = 0.372) (Table 5). The meal % energy from added sugars differed across meals in both men [$F_{1.4, 19.8}$ = 6.1, p = 0.014] and women (χ^2= 32.4, p < 0.0001). In men, it was found that % snacks energy from added sugars was significantly higher compared to % breakfast (p = 0.007), lunch (p < 0.001), and dinner (p < 0.001) energy from added sugars. Percent lunch energy from added sugars was also significantly higher than the % dinner energy from added sugars (p = 0.031). In women, % snack energy from added sugars was significantly higher compared to % breakfast (Z =-3.65, p < 0.001), lunch (Z =-4.29, p < 0.001), and dinner (Z =-4.35, p < 0.001) energy from added sugars, with breakfast and dinner (Z =-3.00, p = 0.003) also containing significantly different percentages of energy from added sugars. While the median energy intake (kcal/d) per snack was 329.4 ± 169.9 kcal in men and 278.7 ± 93.0 kcal in women, 20.1 ± 14.0 % and 18.4 ± 6.4% of snack energy value came from added sugars in men and women, respectively. Overall, the meals with the highest % meal energy from added sugars were snacks (20% in men and 18% in women), even though beverages only contained similar % energy from added sugars (20% in men and 8% in women). Out of main meals, breakfast contained the highest % meal energy from added sugars (9% in men and women), even though its proportion was similar to % meal energy from added sugars from lunch (8% in men and 6% in women) and dinner (4% in men). The meal with the lowest % meal energy from added sugars was dinner (4% in men and women), however, breakfast (9% in men), lunch (6% in women), and beverages only (20% in men and 8% in women) had similar % energy from added sugars to dinner.

The % added sugars from breakfast (Z = -0.55, p = 0.586), lunch (Z = -1.63, p = 0.102), dinner (Z = -0.94, p = 0.349), snacks (Z = -0.96, p = 0.335), and beverages only (Z = -0.98, p = 0.329) (based on added sugars g/d) was similar between men and women for all meal types. The contribution of added sugars differed by meal type in men [$F_{2.5, 35.4} = 14.3$, $p < 0.001$] (**Figure 2A**) and women ($\chi^2 = 39.744$, $p < 0.001$) (**Figure 2B**). The posthoc analysis revealed that in men, the % added sugars from lunch was significantly different from breakfast (p < 0.001), dinner (p < 0.001), and snacks (p < 0.001). The Wilcoxon signed rank test analysis revealed that in women, the % added sugars from snacks was significantly different from breakfast (Z = -3.46, p = 0.001), lunch (Z = -4.05, p < 0.001) dinner (Z = -4.05, p < 0.001), and beverages only (Z = -4.00, p < 0.001). Snacks contributed the highest percentage of added sugars in women (44%). Although, in men, snacks also provided the highest % added sugars compared to other meals (38%), the estimate was not statistically significantly different from % added sugars from breakfast (22%), dinner (17%), and beverages only (14%). Beverages only contributed the lowest percentage of added sugars (14% in men and 6% in women), however, breakfast (22% in men and 19% in women), lunch (29% in men and 22% in women), dinner (17% in men and 12% in women), and snacks (38% in men) contained similar percentages of added sugars.

A: Males[1]



B: Females[2]

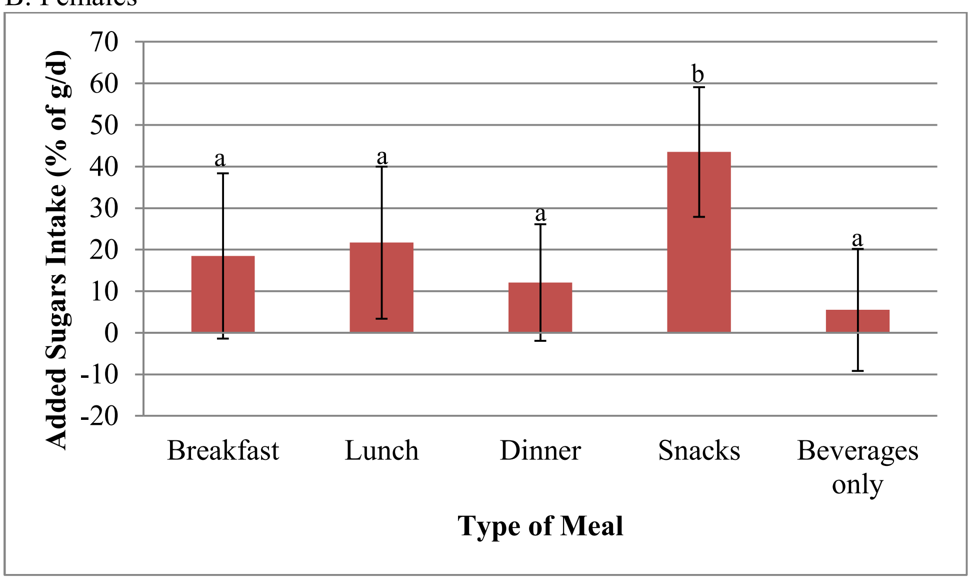


Figure 2: 15-day Mean Added Sugars (% of g/d intake) by Meal type from Healthy (A) Male (n = 15) and (B) Female (n = 25) Participants in a Highly Controlled 15-day Feeding Study Living in the Phoenix Metro Area

[1] Repeated Measures ANOVA [$F_{2.5,\ 35.4} = 14.3$, $p < 0.001$] with post hoc tests was run to test whether there was a significant difference in % added sugars between meals. A different letter indicates a statistically significant difference ($p < 0.05$). Data are expressed as % Median ± Interquartile Range.

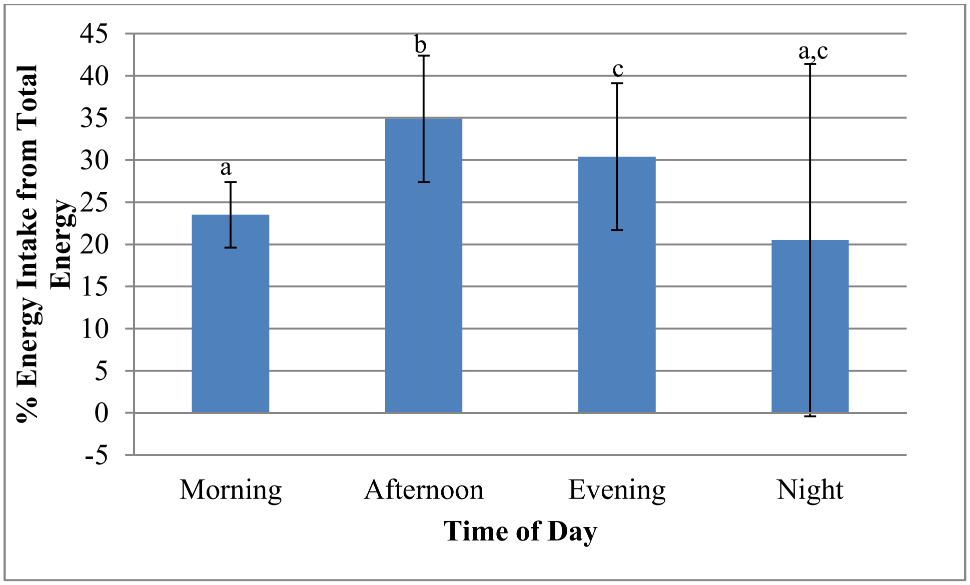
[2] Friedman test [$\chi^2 = 39.7$, $p < 0.001$] and Wilcoxon Signed Rank Test with Bonferroni correction was run to test whether there was a significant difference in % added sugars between meals. A different letter

indicates a statistically significant difference ($p < 0.005$, respectively). Data are expressed as % Median ± Interquartile Range.

Energy intake by time of day

Percent energy contribution from the morning (t = -0.24, p = 0.813), afternoon (t = 0.67, p = 0.510), evening (t = -1.03, p = 0.307), and night (t = 1.12, p = 0.238) was similar between men and women. Percent energy contribution differed by time of day in both sexes [men: $F_{1.4, 19} = 13.3$, p = 0.001 (**Figure 3A)**; women: $F_{3,72} = 281.3$, $p < 0.001$ (**Figure 3B**)], although, in men, percent energy contribution was similar between morning and night (p = 0.079), and the evening and night (p = 1.00). In women, the percent energy contribution significantly differed between all times of day ($p < 0.05$). Overall, the highest energy contribution came from the afternoon intake (35% in men and 34% in women). The lowest energy contribution came from night intake (21% in men and 16% in women), however, energy contribution from night intake was similar to morning intake (24%) and evening intake (30%) in men.

A: Males



B: Females

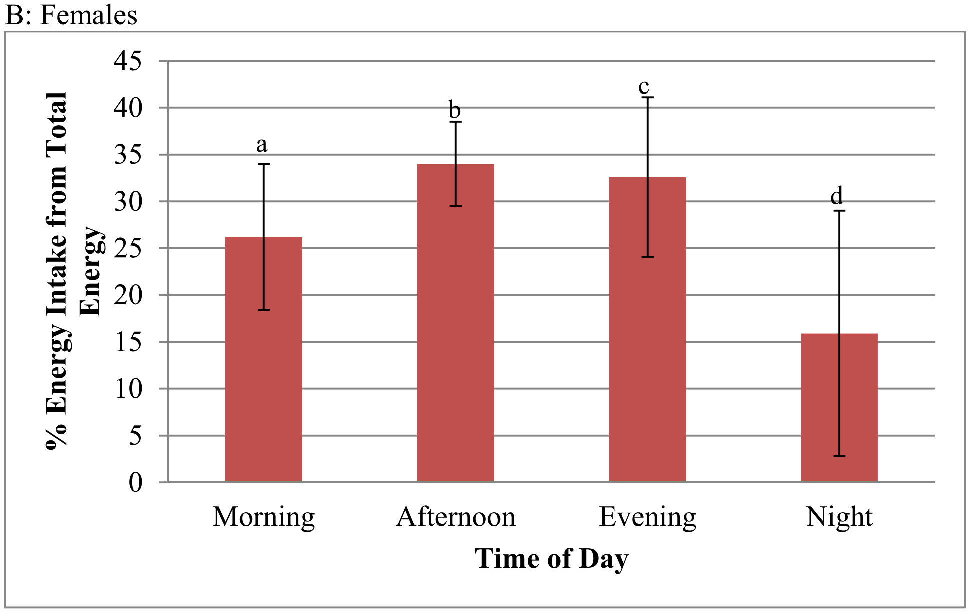


Figure 3: %15-day Mean Energy Intake by Time of Day from Healthy Male (n = 15) and Female (n = 25) Participants in a Highly Controlled 15-day Feeding Study Living in the Phoenix Metro Area

Repeated Measures ANOVA [males: $F_{1.4, 19} = 13.3$, $p = 0.001$; females: $F_{3, 72} = 281.3$, $p < 0.001$] with post hoc tests was run to test whether there was a significant difference in % energy between times of day. A different letter indicates a statistically significant difference ($p < 0.05$). Data are expressed as % Median ± Interquartile Range.

Men and women differed in their energy intake (kcal/d) during the morning ($t = 2.51$, $p = 0.016$) and afternoon ($t = 3.69$, $p = 0.001$), but not during the evening ($t = 1.43$, $p = 0.161$) and at night ($t = 1.64$, $p = 0.110$) (**Table 6**).

Table 6. 15-day Mean Energy and Added Sugars Intake by Time of Day[1] and Sex from Healthy Participants in a Highly Controlled 15-day Feeding Study living in the Phoenix Metro Area (n = 40)[2-5]

	Energy intake (kcal/d)		**Time of day Energy from added sugars (%)**	
Time of day	Men (n = 15)	Women (n = 25)	Men (n = 15)	Women (n = 25)
Morning	707.6 (174.1)[a]	574.9 (263.6)[a]	13.2 (9.9)[a]	9.8 (11.4)[a]
Afternoon	1106.4 (318.0)[b]	820.4 (247.2)[b]	10.4 (10.9)[b]	9.6 (4.5)[b]
Evening	979.8 (410.5)[c]	763.2 (335.1)[c]	5.6 (8.3)[c]	8.2 (6.3)[b]
At night	660.3 (619.8)[d]	367.1 (397.3)[a]	11.3 (10.9)[b]	16.2 (13.2)[d]

[1] Morning: 5:00 am-10:59 am, Afternoon: 11:00 am-3:59 pm, Evening: 4:00 pm-7:59 pm, Night: 8:00 pm-4:59 am.
[2] Values are median (interquartile range).
[3] Repeated measures ANOVA with post hoc tests were run to test whether there was a significant difference in energy intake or % time of day energy from added sugars by time of day (comparison by column). A different letter indicates a statistically significant difference ($p < 0.05$).

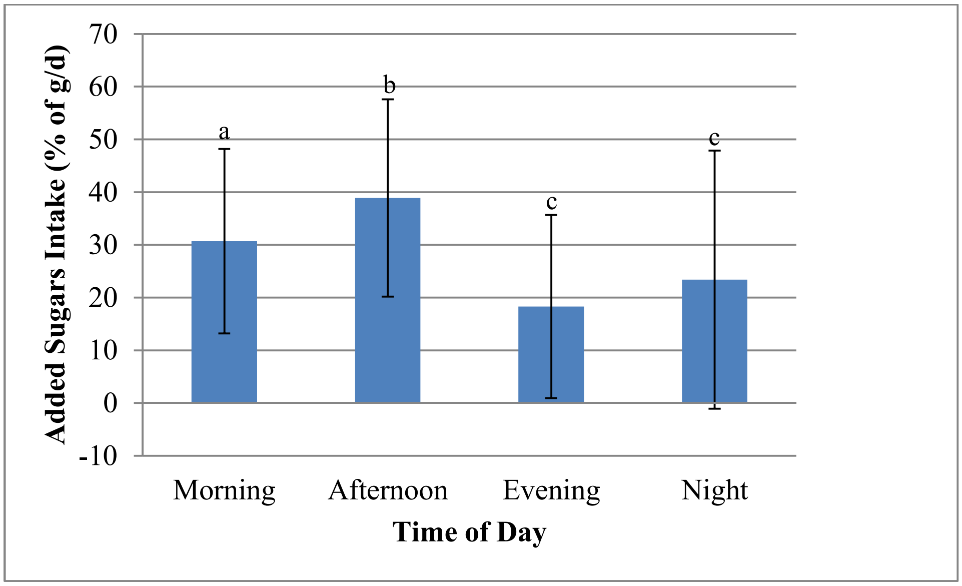
Energy intake (kcal/d) contribution differed by time of day in both men [$F_{1.3, 18.2} = 87.0$, $p < 0.001$] and women [$F_{1.0, 24.1} = 463.6$, $p < 0.001$], and was only similar between morning and at night in women ($p = 0.353$). Overall, the highest amount of energy was consumed in the afternoon (1106 kcal/d in men and 820 kcal/d in women) and the least during the morning (708 kcal/d in men and 575 kcal in women), although energy consumed in the morning was similar to energy consumed at night in women (367 kcal/d).

Added sugars intake by time of day

The % time of day energy from added sugars from the morning ($t = 1.22$, $p = 0.231$), afternoon ($t = 1.33$, $p = 0.200$), evening ($t = -0.04$, $p = 0.972$), and at night ($t = -1.49$, $p = 0.146$) were similar between men and women (Table 6). The % time of day energy from added sugars differed in both men [$F_{1.2, 16.4} = 49.1$, $p < 0.001$] and women [$F_{1.6, 37.5} = 33.6$, $p < 0.001$]. It was found that the contribution from added sugars to time of day energy differed between all time periods except for afternoon and at night ($p = 1.000$) in men and afternoon and evening ($p = 1.000$) in women. The % time of day energy from added sugars was highest from the morning intake (13%) in men and at night intake (16%) in women and was lowest from the evening intake in men (6%) and women (8%), however the % time of day energy from the evening was similar to afternoon (10%) intake in women.

Percent added sugars contribution from morning ($t = 0.50$, $p = 0.623$), afternoon ($t = 1.22$, $p = 0.237$), evening ($t = -1.49$, $p = 0.146$), and at night ($t = 0.06$, $p = 0.952$) intake (from added sugars, g/d) was also similar in men and women. The percent added sugars contribution differed by time of day in both men [$F_{1.1, 14.7} = 92.9$, $p < 0.001$] (**Figure 4A**) and women [$F_{2.1, 50.9} = 6.9$, $p = 0.002$] (**Figure 4B**).

A: Males



B: Females

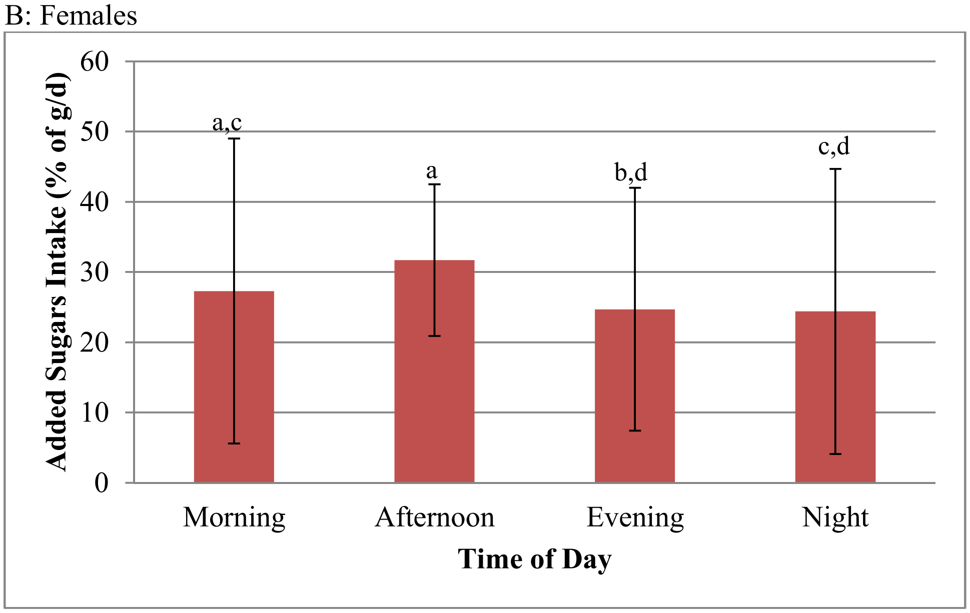


Figure 4: 15-day Mean Added Sugars (% of g/d intake) by Time of day from Healthy Male (n = 15) and Female (n = 25) Participants in a Highly Controlled 15-day Feeding Study Living in the Phoenix Metro Area

Repeated Measures ANOVA [males: $F_{1.1, 14.7} = 92.9$, $p < 0.001$; females: $F_{2.1, 50.9} = 6.9$, $p = 0.002$] with post hoc tests was run to test whether there was a significant difference in % added sugars between times of day. A different letter indicates a statistically significant difference ($p < 0.05$). Data are expressed as % Median ± Interquartile Range if skewed.

In men, percent added sugars intake significantly differed in all time periods except for the evening and at night ($p > 0.05$). In women, it was found that percent added sugars intake in the evening significantly differed compared to the morning ($p = 0.032$) and afternoon ($p = 0.002$), and that the % added sugars intake from the afternoon also significantly differed from at night intake ($p = 0.005$). In men, the highest percentage of added sugars was consumed in the afternoon (39%). Although percent added sugars contribution from afternoon intake was also highest among women (32%), added sugars contribution from the morning intake (27%) was not statistically significantly different.

Correlation between Energy and Added Sugars Intake by Meal Type, Time of Day, Frequency of Eating, Age, Physical Activity, and Body Mass Index

Total EO frequency (with and without beverages only) had a significant inverse correlation with TEI ($r = -0.31$, $p < 0.05$ and $r = -0.42$, $p < 0.01$, respectively) and was significantly positively correlated with active MET-hours ($r = 0.32$, $p < 0.05$ and $r = 0.37$, $p < 0.05$, respectively) (**Table 7** and **Table 8**).

Table 7. Correlation coefficients between energy and added sugars intake by meal type, frequency of eating, age, physical activity and BMI (n = 40)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1 Log10 (Age, years)																											
2 Active MET hours	-0.20																										
3 Total EO frequency	0.06	.32*																									
4 Total EO frequency (no beverages only)	0.06	.37*	.89**																								
5 BMI	-0.03	-0.19	-0.10	0.05																							
6 sqrt (TEI)	-0.26	-0.02	-.31*	-.42**	0.08																						
7 % energy from AS	0.21	-0.27	-0.24	-0.25	0.01	-0.08																					
8 sqrt (% energy from AS from breakfast)	0.06	-0.27	-0.26	-0.20	0.16	0.05	.63**																				
9 sqrt (% energy from AS from lunch)	0.16	-0.16	-.42**	-.43**	-0.21	0.11	.72**	0.27																			
10 Log10 (% energy from AS from dinner)	-0.10	-0.19	-.42**	-.34*	-0.13	0.09	.46**	0.06	.50**																		
11 % energy from AS from snacks	0.24	-0.16	-0.13	-0.07	0.23	-0.17	.62**	0.27	.34*	0.20																	
12 % energy from AS from beverages only[1]	0.10	-0.16	-0.08	-0.22	-0.12	0.05	.45**	0.31	0.27	0.06	-0.03																
13 sqrt (% breakfast energy from AS)	-0.04	-0.29	-0.27	-0.20	0.25	0.12	.58**	.94**	0.24	0.10	0.21	0.26															
14 sqrt (% lunch energy from AS)	0.25	-0.18	-0.30	-.34*	-0.26	0.01	.71**	0.24	.93**	.46**	.35*	.35*	0.20														
15 sqrt (% dinner energy from AS)	-0.03	-0.19	-0.31	-0.25	-0.15	-0.01	.58**	0.11	.53**	.94**	0.29	0.17	0.10	.48**													
16 % snack energy from AS	0.22	-.36*	-.46**	-.50**	0.08	0.04	.70**	0.29	.62**	.41**	.71**	0.06	0.26	.55**	.42**												
17 % beverages only energy from AS[1]	0.12	-0.11	-0.11	-0.19	-0.16	-0.04	0.30	0.09	.32*	0.04	-0.09	.89**	0.04	.37*	0.13	0.05											
18 % AS from Breakfast	-0.08	-0.15	-0.24	-0.15	0.24	0.18	0.24	.88**	-0.06	-0.12	-0.03	0.08	.85**	-0.11	-0.15	0.01	-0.11										
19 % AS from Lunch	0.00	-0.06	-.44**	-.46**	-0.27	0.20	0.22	-0.10	.79**	0.28	-0.02	0.16	-0.07	.68**	0.23	.34*	.37*	-0.25									
20 sqrt (% AS from Dinner)	-.33*	-0.08	-.38*	-.33*	-0.11	0.28	-0.21	-.37*	0.03	.68**	-0.27	-0.13	-0.29	-0.01	.54**	-0.05	-0.13	-0.30	0.18								
21 % AS from Snacks)	0.22	0.07	0.21	0.28	0.14	-0.27	0.01	-0.27	-0.14	-0.02	.68**	-.36*	-0.29	-0.06	-0.03	0.27	-0.29	-.36*	-0.27	-0.23							
22 % AS from Beverages only[1]	0.11	-0.11	0.06	-0.15	-0.20	0.04	0.24	0.19	0.11	-0.0591	-0.20	.94**	0.13	0.19	0.03	-0.09	.88**	0.03	0.12	-0.15	-.39*						
23 % energy from Breakfast	0.28	-0.08	-0.07	-0.10	-0.22	0.00	.35*	.43**	0.25	0.09	0.25	0.22	0.15	.31*	0.18	0.24	0.19	0.29	-0.02	-0.17	-0.02	0.23					
24 % energy from Lunch	-0.17	-0.22	-.64**	-.57**	0.02	0.25	0.12	0.08	.44**	0.23	0.00	0.11	0.13	0.14	0.20	.37*	0.21	0.06	.57**	0.21	-0.24	0.08	-0.19				
25 % energy from Dinner	-0.23	-0.17	-.63**	-.60**	-0.07	.32*	-0.21	-0.20	0.10	.38*	-0.21	-0.13	-0.07	0.10	0.12	0.11	-0.06	-0.10	.35*	.67**	-0.16	-0.18	-.34*	0.30			
26 sqrt (% energy from Snacks)	0.11	0.13	.49**	.57**	0.22	-.35*	-0.06	-0.07	-.38*	-0.29	.43**	-0.05	-0.07	-0.28	-0.17	-0.22	-0.14	-0.13	-.52**	-.31*	.61**	-0.04	-0.10	-.41**	-.45**		
27 sqrt (% energy from Beverages only)	0.06	-0.26	-0.13	-0.26	-0.12	.38*	0.22	.50**	0.11	-0.06	-0.12	.58**	.49**	0.11	-0.05	-0.01	.35*	.48**	0.03	-0.17	-.40**	.56**	0.23	0.07	0.01	-0.27	

MET: Metabolic equivalents, EO: eating occasion, AS: added sugars

[1] Spearman correlation with non-transformed variables was used for skewed variables that could not be transformed. Pearson correlation was used for normally distributed or transformed variables.

* $p < 0.05$, ** $p < 0.01$

Table 8. Correlation coefficients between energy and added sugars intake by time of day, frequency of eating, age, physical activity and BMI (n = 40)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1 Log10 (Age, years)																							
2 Active MET hours	-.2																						
3 Total EO frequency	.06	.32*																					
4 Total EO frequency (no beverages only)	.06	.37*	.89**																				
5 BMI	-.03	-.19	-.1	.05																			
6 sqrt (TEI)	-.26	-.02	-.31*	-.42**	.08																		
7 % Energy from AS	.21	-.27	-.24	-.25	.01	-.08																	
8 % Energy from AS from the morning	.21	-.33*	-.15	-.12	.1	-.02	.58**																
9 sqrt (% Energy from AS from the afternoon)	.2	-.15	-.23	-.25	-.15	.08	.85**	.44**															
10 % Energy from AS from the evening	-.02	-.03	-.03	-.01	-.01	-.17	.59**	-.02	.44**														
11 sqrt (% energy from AS from at night)	.07	.03	-.11	-.15	.15	-.22	.38*	-.08	.12	.27													
12 % morning energy from AS	.09	-.33*	-.26	-.24	.08	.07	.61**	.91**	.48**	.01	-.01												
13 sqrt (% afternoon energy from AS)	.2	-.21	-.22	-.3	-.2	.05	.80**	.40*	.92**	.44**	.18	.43**											
14 sqrt (% evening energy from AS)	-.15	-.12	-.15	-.13	.	-.11	.51**	-.06	.43**	.84**	.24	-.02	.38*										
15 sqrt (% night energy from AS)	.40*	-.09	.24	.19	.24	-.36*	.37*	.07	.13	.24	.79**	-.01	.17	.16									
16 % AS from the morning	.06	-.15	-.06	-.03	.12	.11	.07	.82**	.02	-.45**	-.36*	.71**	-.01	-.44**	-.21								
17 % AS from the afternoon	.15	.05	-.14	-.16	-.26	.18	.33*	.05	.74**	.11	-.17	.09	.66**	.18	-.17	-.15							
18 % AS from the evening	-.08	.13	.15	.18	-.03	-.14	-.02	-.41**	-.06	.75**	-.06	-.41**	-.02	.59**	.	-.56**	-.08						
19 % AS from at night	-.07	.11	-.07	-.12	.18	-.14	-.12	-.43**	-.32*	-.01	.81**	-.38*	-.2	.	.57**	-.46**	-.37*	-.06					
20 % Energy from the morning	.35*	-.1	.24	.18	-.12	-.09	.26	.53**	.23	-.03	-.14	.21	.27	-.11	.19	.48**	.04	-.18	-.31				
21 % Energy from the afternoon	-.12	-.02	-.15	-.06	.13	.16	.15	.28	.32*	-.07	-.32*	.32*	.02	.17	-.3	.32*	.39*	-.23	-.45**	-.05			
22 % Energy from the evening	.37*	-.04	.05	.11	.05	-.08	.07	-.04	.1	.41**	-.13	-.08	.2	.01	.06	-.19	.09	.55**	-.11	-.02	-.39*		
23 % Energy from at night	-.41**	.03	-.52**	-.52**	-.04	.31	-.09	-.1	-.08	-.23	.36*	.09	-.01	.02	-.11	-.02	-.05	-.31	.43**	-.44**	.03	-.47**	

MET: Metabolic equivalents, EO: eating occasion, AS: added sugars
* p < 0 .05, ** p < 0.01

Further, total EO frequency was significantly inversely correlated with % energy and % energy from added sugars from lunch (energy: $r = -0.64$, $p < 0.01$; added sugars: $r = -0.42$, $p < 0.01$) and dinner (energy: $r = -0.63$, $p < 0.01$; added sugars: $r = -0.42$, $p < 0.01$) (Table 7). While total EO frequency was significantly positively associated with the percent energy from snacks ($r = 0.49$, $p < 0.01$), the association between total EO frequency and % snack energy from added sugars was significantly inverse ($r = -0.46$, $p < 0.01$). Findings for total EO frequency (no beverages only) followed the same trend. It was also found that TEI had a significant positive association with the % energy from dinner ($r = 0.32$, $p < 0.05$) and beverages only ($r = 0.38$, $p < 0.05$), and a significant negative association with the percent energy from snacks ($r = -0.35$, $p < 0.05$). Furthermore, age had a significant positive association with the % night energy from added sugars ($r = 0.40$, $p < 0.05$), while TEI had a significant inverse association with the % night energy from added sugars ($r = -0.36$, $p < 0.05$) (Table 8). Total EO frequency was significantly inversely associated with % energy at night ($r = -0.52$, $p < 0.01$). Also, the % energy from added sugars was significantly positively associated with % added sugars from the afternoon ($r = 0.33$, $p < 0.05$).

Predictors of Total Energy Intake and Body Mass Index

A multiple linear regression model was fitted to investigate whether percent energy by meal type, sex, age, and total EO frequency would predict TEI (**Table 9**).

Table 9. Multiple Linear Regression Models Regressing Total Energy Intake on % Energy by Meal Type, Sex, Age, and Total Eating Occasion Frequency

	β coefficient	**S.E.**	**p value**	**Adjusted R^2**	**p value**
Exploratory model					
% energy from breakfast	-0.13	0.19	0.504		
% energy from lunch	-0.03	0.18	0.886		
% energy from dinner	0.05	0.17	0.778		
sqrt (% energy from snacks)	-0.89	1.09	0.420		
sqrt (% energy from beverages only)	1.21	0.53	0.030		
Sex (males)	4.88	1.35	0.001		
Log10 (Age, years)	-3.72	4.41	0.406		
Total EO frequency	-0.24	1.26	0.850		
Adjusted R^2				0.40	0.002
Final model					
sqrt (% energy from beverages only)	1.21	0.50	0.021		
Sex (males)	5.36	1.21	< 0.001		
Adjusted R^2				0.41	0.001

EO: eating occasion

Among all investigated variables, we found that % energy from beverages only and sex were significant predictors of TEI and remained in the final model (Adjusted $R^2 = 0.41$, $p < 0.001$). In another multiple linear regression model predicting TEI based on percent energy by time of day, sex, age, and total EO frequency, we found that % energy from at night and sex best predicted TEI (Adjusted $R^2 = 0.36$, $p < 0.001$) (**Table 10**), while none of the other variables were found to be significant predictors of TEI.

Table 10. Multiple Linear Regression Models Regressing Total Energy Intake on % Energy by Time of Day, Sex, Age, and Total Eating Occasion Frequency

	β coefficient	**S.E.**	**p value**	**Adjusted R^2**	**p value**
Exploratory model					
% energy from the morning	0.14	0.13	0.313		
% energy from the afternoon	0.23	0.16	0.160		
% energy from the evening	0.22	0.12	0.092		
% energy from at night	0.18	0.10	0.093		
Sex (males)	5.21	1.35	0.001		
Log10 (Age, years)	-4.80	5.03	0.348		
Total EO frequency	0.13	0.88	0.885		
Adjusted R^2				0.349	0.003
Final Model					
% energy from at night	0.09	0.06	0.126		
Sex (males)	5.42	1.27	< 0.001		
Adjusted R^2				0.363	< 0.001

EO: eating occasion

Similarly, a multiple linear regression model was generated to predict TEI based on the percent added sugars by meal type, sex, age, and total EO frequency (no beverages only) (**Table 11**).

Table 11. Multiple Linear Regression Models Regressing Total Energy Intake on % Added Sugars by Meal Type, Sex, Age, and Total Eating Occasion Frequency (no beverages)

	β coefficient	S.E.	p value	Adjusted R^2	p value
Exploratory model					
% AS from Breakfast	0.064	0.074	0.397		
% AS from Lunch	-0.004	0.072	0.956		
sqrt (% AS from Dinner)	0.793	0.683	0.254		
% AS from Snacks	-0.013	0.059	0.825		
Sex (males)	4.802	1.448	0.002		
Log10 (Age, years)	-2.044	4.737	0.669		
Total EO frequency (no beverages only)	-0.666	1.020	0.519		
Adjusted R^2				0.333	0.004
Final model					
% AS from Breakfast	0.086	0.053	0.113		
sqrt (% AS from Dinner)	1.099	0.520	0.042		
Sex (males)	5.293	1.230	< 0.001		
Adjusted R2				0.394	< 0.001

EO: eating occasion
AS: added sugars

We found that the % added sugars from dinner and sex were significant predictors of TEI, and while the % added sugars from breakfast was not a significant predictor in the exploratory models, it did improve the predictability of the final model (Adjusted $R^2 = 0.39$, $p < 0.001$). A model was also fitted to predict TEI based on the percent added sugars by time of day, sex, age, and total EO frequency, but none of the variables were significant predictors of TEI ($p > 0.05$) (data not shown). Models were also fitted to investigate whether percent energy or percent added sugars by meal type or time of day, along with sex, age, physical activity, and TEI would predict BMI, but none of the variables were significant predictors (data not shown).

CHAPTER 5

DISCUSSION

The purpose of this analysis was to describe patterns of added sugars consumption in U.S. adults consuming their usual diet and to study the association between dietary sugars, eating patterns, TEI, and BMI. This is the first study to investigate patterns of added sugars consumption in the U.S. population. Research that have investigated added sugars consumption in the U.S. population have relied on limited number of days of self-reported intake. Our study population included 40 healthy adults living in the Phoenix area who participated in a 15-day highly controlled feeding study, which imitated participants' usual diet.

Added sugars intake

Our study participants consumed an average of 9.7 ± 5.4 % energy from added sugars, which meets the current recommendations for added sugars according to the 2015-2020 USDA Dietary Guidelines for Americans (≤ 10%).[6] Based on dietary data from NHANES, the % energy from added sugars intake in the general U.S. population from 2011-2012 was approximately 14%.[5] Our results may have been low due to our small sample size (n=40), which mainly consisted of white women with a higher education level and high annual family income. Based on frequency data on major food and beverage sources of added sugars from the 2005 NHIS[38] (n = 28,948) and 2010 NHIS[39] (n = 24,967), race (African American or Hispanic) and sex (males) were significant determinants of high added sugars intake.[38,39] In our study, added sugars intake did not differ by race, sex, or social economic factors, however, our study lacked demographic heterogeneity.

Snacks contained the highest percent energy from added sugars compared to main meals (20% ± 14% in men and 18% ± 6% in women). Yet, beverage only occasions contained a similar proportion of energy from added sugars (20% ± 36% in men and 8% ± 30% in women). Currently, this is the only study that has investigated % energy from added sugars by meal type energy. This is not surprising, since common snack foods in U.S. adults tend to be high in added sugars, such as candies, cakes, pastries, and pies, dairy desserts, and cookies.[77]

When exploring the contribution to added sugars intake (% of g/d) by meal type, in women, snacks contributed the highest proportion of added sugars intake (44%). In men, snacks contributed a similar proportion of added sugars to women (38%), however, it was similar to other meal types. Our results were partially supported by a cross-sectional study by Louie et al[19] that investigated patterns of % added sugars intake by meal type in a representative sample of the Australian adult population (n=5,725) with the use of one 24HDR. Similar to our findings, snacks were the greatest contributors of added sugars in adults age 19 - 70 years old [men (44% - 48%); women (48% - 53%)].[19] Furthermore, Louie et al[19] found that breakfast/brunch contributed the highest percentage of added sugars from main meals [men (20% - 25%); women (19% - 20%)], while in our population lunch was the biggest contributor to added sugars intake in men (28.5%), with there being no significant difference among main meals in women. In their adults, sugar and sweet spreads (45%), breads and cereals (22%), and SSB (12.8%) were the highest contributors to added sugars intake from breakfast.[19] In contrast, SSB (49%) and cake, pastries, biscuits, and batter-based products (12%) were the highest contributors to total added sugars intake from lunch.[19] Differences in study population, sample size, food preferences and intake, dietary assessment methods, and the number of days of dietary data collected may explain the different results in our study versus Louie et al's study.[19] Currently, this is the only study that has investigated added sugars intake by time of day. Percent time of day energy from added sugars was highest during the morning in men (13%) and at night time in women (16%), and lowest during the evening in men (6%) These results may differ by sex due to women and men eating sugary snacks and beverages at different times of the day.

Total Energy Intake

The mean TEI was 2715.3 ± 712.4 kcal and was significantly higher in men (3016.3 ± 549.7 kcal) than women (2373.5 ± 484.7 kcal). Ford et al[51] investigated TEI trends in U.S. adults (n = 63,761) with the use of 24HDR from nine NHANES surveys (1971-2010) and reported lower intakes. In contrast to our results, mean TEI adjusted for age, sex, education level, race, and BMI was 2195.1 ± 17.3 kcal in adults according to NHANES 2009 - 2010.[51] No significant increase in body weight was observed over the 15-d feeding period, though the protocol may have encouraged increased energy intake due to all the food being prepared for them, the food was readily accessible, and the participants were given a higher quantity of food then they would normally consume. One of the major limitations of self-reports is energy under-reporting. Studies comparing self-report dietary assessment methods (food diaries and 24HDR) to doubly labeled water (DLW) have found that energy is being under-reported by 20% to 33%, respectively,[78,79] while these methods explained only 7.8% and 2.8% of the variation in the energy biomarker, respectively.

In our study, across meals, the highest energy contribution came from dinner (1019 kcal in men and 720 kcal in women), and the lowest from breakfast (587 kcal in men and 512 kcal in women). Our results were partially supported by a study by Howarth et al[16], who used data from two 24HDR from the 1994-1996 USDA CSFII in younger (20 – 59 years, n = 1,792) and older adults (60 – 90 years, n = 893). Similar to our study, they found that the highest contribution to energy intake (kcal/d) came from dinner (914 kcal in younger adults and 766 kcal in older adults), while snacks and breakfast provided similar amounts of kcal in older adults (355 and 404 kcal, respectively) but not in younger adults (469 and 377 kcal, respectively).[16] In our population, energy from snacks (kcal) was 704 kcal in men and 549 kcal in women, and was significantly higher than energy from breakfast (kcal) in both men (587 kcal) and women (512 kcal). The mean energy intake (kcal/d) per snack in our population was 329 kcal in men and 279 kcal in women. Kant et al[20] used one 24HDR from nine NHANES surveys in a representative sample of U.S. adults age 20 – 74 years (n = 62,298), and found that snacking has increased by approximately 135 kcal from 1971 – 2010 in both men (502 ± 15 kcal/d to 634 ± 13 kcal/d) and women (296 ± 7 kcal/d to 438 ± 8 kcal/d). Further, Piernas et al[50] found that energy per snack was 226 ± 3.68 kcal during 2003-2006. Piernas et al[50] used participant identified meal coding in their study. Snacks were identified as “snack” by the participant, with coffee or beverage only occasions also counting as snacks.[50] Differences in meal coding may explain the different results. Further, the consumption of multiple snacks throughout the day may help explain why the % energy from snacks was significantly higher than the % energy from breakfast, which is known as the main meal with the lowest contribution to % energy.

In our population, the highest energy contribution came from afternoon intake (11:00 am – 3:59 pm) [men: 1106 kcal (35%); women: 820 kcal (34%)]. Kant et al[20] found that during the afternoon time period a snack was consumed in addition to a main meal, which increased the % energy consumed in that time period by approximately 13%. In the evening (4:00 pm – 7:59 pm) only one main meal was consumed.[20] Snacking during the afternoon time period may explain why the afternoon had the highest energy contribution in our study.

Eating Occasion Frequency

The number of EOs per day in our population was 5.1 ± 1.5 in men and 5.4 ± 1.3 in women. Our results were supported by a cross-sectional study by Kant et al,[49] which used a 24HDR from four NHANES surveys from 1971-2002 in a representative sample of U.S. adults (n = 39,094) to assess EF. They found that the mean daily EO was 5.1 ± 0.1 in men and 5.0 ± 0.04 in women from 1999-2002.[49] The evidence on whether EO frequency has increased over time is inconclusive, with some studies indicating that EOs have slightly increased[49], while others are reporting a large increase in daily EO frequency.[21] In our participants, the frequency of snacks was 1.5 ± 1.2 in men and 2.0 ± 0.9 in women, with it being significantly higher in women. Our results were partially supported by a study by Kant et al,[49] that found that, from 1971 to 2010, SF increased in women (2.09 ± 0.04 to 2.30 ± 0.04; $p_{trend} < 0.0001$), but decreased in men (2.45 ± 0.05 to 2.23 ± 0.03; $p_{trend} = 0.004$). This study did not test for significant differences in SF between men and women, however SF appeared higher in women.[20] We used 15-days of dietary measurements, which can better characterize snacking habits compared to one 24HDR used by Kant et al[49]. Furthermore, Kant et al[20] regarded beverage only occasions as snacks, while we analyzed them as separate EOs, which further explains the difference in findings between the two studies.

Correlations between Eating Occasion Frequency and Total Energy Intake, Body Mass Index, and Energy and Added Sugars Intake by Meal Type and Time of Day

Eating frequency was inversely associated with TEI ($r = -0.31$, $p<0.05$) in our study population. In contrast, Kerver et al[13] (n=15,978), using one 24HDR from NHANES 1988 to1994,[13] and Mills et al[62] (n = 1,009 middle aged women), using a 1-day food diary, found a positive association between EF and TEI. Kerver et al[13] reported that more frequent eaters had a higher TEI (e.g., EF 1-2: 1,446 ± 60 kcal; EF ≥ 6: 2,540 ± 35 kcal; $p < 0.0001$). Mills et al[62] found a weak positive association between EF and TEI ($r = 0.20$; $p < 0.0001$). In the current study, an increase in EF was associated with a significant decrease in the % energy from added sugars from lunch ($r = -0.42$, $p < 0.01$) and dinner ($r = -0.42$, $p < 0.01$), and % snack energy from added sugars ($r = -0.46$, $p < 0.01$). Currently there is no research that has investigated the relationship between EF and added sugars intake. However, Kerver et al[13] found that more frequent eaters had increased carbohydrate intakes (p <0.0001), while less frequent eaters had increased fat (p <0.0001) and protein intakes (p = 0.0002). Our findings suggest that high snackers in our population were not snacking on high sugar snacks and were less likely to have high sugar foods for lunch and dinner. We found no significant relationship between EF and BMI. Similarly, a study by Barnes et al[29] found no significant relationship between SF and BMI in a sample of adults (n = 233). However, research investigating EO frequency and BMI is currently inconclusive. Studies by Howarth et al,[16] Murakami et al,[14] and Kahleova et al[15] reported a positive association [14-16] between EF and BMI, while studies by Keast et al[17] and Yunsheng et al[18] reported a negative association[17,18]. Due to our small sample size (n=40), our study may have lacked the statistical power to investigate the association between EF and BMI.

Predictors of Total Energy Intake

Our study is the first to look at the relationship between TEI and % energy and % added sugars by meal type. We found a significant positive correlation between TEI and % energy from dinner and beverages only and a significant inverse correlation with % energy from snacks. However, results from linear regression models showed that out of those meal types, the % energy from beverages only was a significant predictor of TEI. Using dietary data from one 24HDR from NHANES 2003 – 2008 in U.S. adults (n = 13,704), Kant et al[80] investigated whether there was an association between energy from beverages and TEI. After adjusting for age, race, years of education, income, BMI, smoking status, self-reported recreational activity, and self-reported chronic disease, they found that with an increase in energy from beverages (kcal) there was an increase in TEI in both men (e.g., T1: 2,118 ± 28 kcal; T3: 3,246 ± 40; $p_{trend} < 0.0001$) and women (e.g., T1:1,468 ± 19 kcal; T3: 2,193 ± 22 kcal; $p_{trend} < 0.0001$).[80] It has been established that beverages are not as satiating compared to solid foods.[81] Beverages have a high consumption rate (>200 g/min) and low oro-sensory exposure time compared to solid foods, therefore resulting in low satiation and increased TEI.[81]

In the current study, we found that the % energy consumed at night was a predictor of TEI. Previous research has shown a relationship between later meal timing (evening and night) and higher TEI. Reid et al[2] used dietary data from consecutive 7-day food diaries in 59 adults and found a positive association between the timing of the last meal and TEI ($r = 0.39$, $p = 0.002$). Using the same study, Baron et al[1] found a positive association between TEI and carbohydrate ($r = 0.56$, $p < 0.001$), fats ($r = 0.60$, $p < 0.001$) and protein ($r = 0.68$, $p < 0.001$) intake after 8 pm and carbohydrate ($r = 0.36$, $p < 0.05$) and protein ($r = 0.43$, $p < 0.05$) intake within four hours of sleep. Therefore, eating at night may play a role in increased TEI.

It was observed that % added sugars from dinner was a significant predictor of TEI, while the % added sugars from breakfast increased the predictability of TEI in the linear regression model. Available literature has observed that out of main meals, breakfast has the highest contribution to added sugars intake (20.6%).[19] Increased added sugars intake at breakfast may be contributed to common sugary foods and beverages consumed at that meal, for example, cereal, pastries, breads, sugar spreads, sweetened coffees, etc.[19] The higher added sugars intake at breakfast may increase its calorie content, which may explain why the % added sugars from breakfast increased the predictability of TEI. Though our study and the available literature [19] has indicated that dinner has a lower contribution to added sugars intake (12-17%), research has shown a significant relationship between later meal timing and increased TEI.[1,2]

Strengths and Limitations

A major strength of this study was that it was a highly controlled feeding study in which we simulated participants' usual diet over 15 days, which allowed us to obtain estimates of their true intake and usual dietary behavior under controlled conditions. We had data on 15 consecutive days of diet, while most research in this area relies on 1-2 days of dietary data since such protocol is cheaper and results in less participant burden. In addition, due to our highly controlled feeding study design, we have collected data on both meal timing and meal composition, although we have relied on self-reported meal and snack times. Though our participants were encouraged to mark down the time that they ate a meal or snack as they were eating it, it is possible that they may have waited until the end of the day or simply forgot, which could have resulted in inaccurate meal timing data. However, as part of the meal checklist protocol, research staff reviewed the meal times with the participant after each feeding day, filling in any gaps and potentially improving the accuracy of the data. The study was relatively small (n = 40), and may have lacked the statistical power to find a significant relationship between EF and BMI, and % energy and % energy from added sugars by meal type or time of day and BMI. Further, a majority of our sample size were white educated women, meaning that our sample was not representative of the Phoenix or U.S. population due to the lack of racial and sex diversity. Furthermore, although our participants had all of their meals prepared for them throughout the 15-d feeding period, our study had a high participant burden. Our participants had to go the study center 5 times per week, fill out daily checklists (Meal Checklist and Physical Activity Log Book), and were only allowed to eat from the food provided by the metabolic kitchen. The high participant burden and study design may have altered our participant's normal eating patterns. More specifically, having all of their food cooked for them and readily available might have increased their EF, since they did not have to stop and cook or buy food for themselves. Nonetheless, no increase in body weight was observed during the 15-d feeding period, indicating that the participants were kept at energy balance throughout the study. Currently, there are no standardized definitions for meals, snacks, and times of day. With that being said, we used a combination of methods (time of day[24,53], participant identified,[20,21,49,50] and meal content[24,52,53]) and additional criteria (combining EO's eaten within 15 minutes of each other[24] and designating beverage only EO's[50]) that have been used in previous research). Further, though our time of day definitions were not standardized, they were modified based on definitions used in previous research.[24,53]

CHAPTER 6

CONCLUSION

The aims of this study were to describe patterns of added sugars consumption, to investigate the relationship between patterns of added sugars and TEI, and to investigate the relationship between patterns of added sugars and BMI. Our study suggests that increasing EO frequency and decreasing energy from beverages only and at night time as well as decreasing added sugars from breakfast and dinner may reduce TEI, potentially reducing BMI. Our study also identified meal types and times of day that had the highest and lowest contribution to TEI (kcal/d) (highest: dinner and afternoon; lowest: beverages and at night) and % energy from added sugars (highest: snacks and afternoon; lowest: dinner or beverages, and evening) among men and women. Our study is the first study to investigate patterns of added sugars. However, our study did have its limitations: a small and unrepresentative sample, self-reported meal and snack times, and the use of non-standardized definitions for meals and snacks. Further research in this area is necessary to investigate patterns of added sugars intake and overall eating patterns. Future research should include a larger and more representative sample. In the future, modifying patterns of eating (EF and meal timing) and added sugars intake may be used as part of successful weight loss interventions, therefore reducing BMI and chronic disease prevalence in the U.S.

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APPENDIX A

STUDY POSTER

Investigation of Biomarkers for Sugars Intake

ARIZONA STATE UNIVERSITY
425 N 5rd Street
Phoenix, AZ 85004

www.Sugarsbio.org

602-827-2545
Sugarsbio@asu.edu

ASU School of Nutrition & Health Promotion

Want to earn $599?

Bored with cooking for yourself?

Are you healthy and 18-70 years old?

Then, we need your help for a 15-day feeding study conducted by ASU researchers. You will be consuming your "usual" diet and all meals will be provided for you. Participation is voluntary.
If you are interested, please call, email or check our website!

Sugarsbio@asu.edu
602-827-2545
www.Sugarsbio.org

APPENDIX B

STUDY INFORMATION SHEET

Study Information Sheet

INVESTIGATION OF BIOMARKERS FOR SUGARS INTAKE

You are invited to participate in our new study. Please, take a few minutes to read about the study and to consider if you would like to take part in it. Your participation is absolutely on a voluntary basis and you may refuse without giving any explanation.

WHAT IS THE PURPOSE OF THE STUDY?

Sugars are thought to play very important role in developing many diseases such as diabetes, cancer and cardiovascular disease. To see if this is true we need to measure the food people eat accurately, and if type of food people eat relates to the sort of diseases they develop. This study will test how accurately urine and blood biomarkers can predict how much sugars people are consuming.

WHY HAVE I BEEN INVITED TO TAKE PART IN THE STUDY?

You are invited to participate because we wish to recruit healthy, non-smoking volunteers, like yourself.

DO I QUALIFY?

- YES, if you (i) are 18-70 years of age, (ii) have a BMI <35 kg/m^2, and (iii) reside in the Phoenix metropolitan area;

- NO, if you (1) suffer from kidney disease or bladder incontinence; (ii) are or have been on any kind of dietary restriction due to a weight loss at any point over the last 4 months; (iii) are on any kind of dietary restriction due to a medical condition; (iv) participated in a diet-related research study over the past 4 months; (v) have type 2 or type 1 diabetes or your fasting blood glucose ≥100 mg/dl or HbA1c ≥5.7% (checked at screening); (vi) smoke, or (vii) are allergic to sunscreen, or any part of aminobenzoate potassium (POTABA) or para-amino benzoic acid (PABA).

WHO IS ORGANISING THE STUDY?

The study is organised by the School of Nutrition and Health Promotion at Arizona State University. Our office is situated in the Arizona Biomedical Collaboration Building 1 on the corner of 5th Street and E Van Buren Street in downtown Phoenix, AZ. Here, in the School of Nutrition and Health Promotion, we are interested in the influence of food on human health.

WHAT WILL BE ASKED FROM ME?

If you decide to take part in the study:

- A **screening fasting blood sample** will be taken to check your plasma glucose and HbA1c level. If your fasting blood glucose <100 mg/dl and HbA1c <5.7%, you will be scheduled for a baseline visit.
- **Your body weight and height will be measured.**
- **You will complete a questionnaire**, with questions on your demographics, lifestyle habits, and personal and family medical history.
- **You will record all the foods and drinks you consume over two weeks**. You will be given a food diary with set of instructions and pictures to help you record your diet. Following each week, you will meet with our Research Kitchen Coordinator and Chef to discuss what you have recorded in your food diary and help us gather more information.
- A week after you have completed the 2-wk food diary, **you will participate in a 15-day feeding study**. During the feeding period, you will be provided with all your food on a daily basis. This is the food that you would usually eat, which we have purchased and prepared for you based on the food diaries you kept over the previous 2 weeks. You will come to our kitchen daily Monday-Friday where you will eat your breakfast or lunch, and then collect your dinner, snacks and breakfast or lunch for the following day. On Fridays, you will collect your food for the entire weekend. We will provide you with cooler bags on wheels to ease the transport of meals to your home. You will be free to eat as much as you like from the food prepared for you, and you will NOT be allowed to consume any foods or drinks prepared outside of our kitchen, besides water, alcohol, and black coffee and tea (no added sugar, sweetener, milk, creamer, etc.). If you drink alcohol, you will record the type and amount consumed; you are allowed to drink wine, beer or spirits (i.e., hard liquor, such as whisky, vodka, tequila, gin, etc.) ONLY. Please note that any alcohol beverages that contain added sugars, fruits, cream, spices, herbs, flowers or nuts, such as liqueurs (e.g., Grand Marnier, schnapps) or cocktails are not allowed. We ask you to keep your intake of coffee and tea consistent throughout the 15-day feeding study. You will keep the unconsumed food/drinks in the respective container/bottle and return them to the metabolic kitchen on your next visit. Please note that no one else is allowed to eat the leftovers, and you have to return all

leftovers to the metabolic kitchen, so we can calculate exactly how much food you have consumed.

- You will **collect nine breath samples during the 15-day feeding study** (three samples per day on three randomly selected days; on the breath collections days, you will collect one breath sample before breakfast, and two others at randomly selected time points during the day).
- **We will collect 3 blood samples from you:** before and at the end of the 15-day feeding study and 5 weeks later.
- **You will collect 24-hour urine every other day during the 15-day feeding study (8 in total)**. On two urine collection days, you will collect each of your urine voids in a separate container. We will give you a trolley bag for carrying urine bottles when away from home. To alleviate your burden, we will organize a pick-up service to collect the 24-h urine from your home the morning after the urine collection day (including weekend and holiday). In order to determine whether the collections are complete, you will be requested to take a capsule of aminobenzoate potassium (POTABA) with your breakfast, lunch and dinner (three capsules per day) on the urine collection days. POTABA is commonly used as a marker for ***urine completeness in research studies***, as it is nearly completely excreted in the urine soon after taking a tablet of POTABA.
- **You will keep study logs during the 15-day feeding study**: a brief physical activity log (<5 minutes to complete), and a meal checklist daily, and a urine collection log on the urine collection days.
- **You will be asked to refrain from taking any dietary supplements** during the feeding study and until collection of the final blood sample.

ARE THERE ANY RISKS OF TAKING PART?

There is no risk related to the participation in the study. Very few side effects have been associated with taking POTABA capsules, the marker for ensuring 24-h urine completeness. Reported side effects include upset stomach and skin allergy. An allergic reaction to sunscreen may indicate that side effects from POTABA may occur. If you are allergic to sunscreens, you may not qualify to participate in the study.

HOW WILL CONFIDENTIALITY BE MAINTAINED?

All details held by us will be treated with strict confidentiality. In all publications resulting from the study, a study number will be used to refer to volunteers. Your identity will be known only by the people conducting the study. At the end of the study we will be happy to explain individual results.

WILL I BE REMUNERATED?

You will receive $10 a day for keeping a record of your diet during the two weeks; $20 per day during the 15-day feeding period; and an extra $159 for completion of the whole study to a total of $599. You may withdraw from the study, without explanation, at any time. If you decide to withdraw, you will only be compensated for the portions of the protocol you completed.

INTERESTED IN PARTICIPATING IN THE STUDY?

Please contact Cassandra Kettenhoven at sugarsbio@asu.edu or 602-827-2545 to complete a brief 2-page screening questionnaire, so we can determine if you are eligible to participate. You can also complete the screening questionnaire through our website at *www.sugarsbio.org*. The information from the screening questionnaire will be used to determine if you are eligible to enter the study, and to describe the recruitment process in reports, however, you will not be identified in any way and under no circumstances. You may also schedule a visit to our study center, located at 425 N 5th St, Phoenix, AZ 85004, to hear more about the study and to ask questions.

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APPENDIX C

SCREENING QUESTIONNAIRE

Screening Questionnaire

We are inviting you to participate in a study to help researchers at Arizona State University identify urine and blood biomarkers that can predict how much sugars people are consuming. You will be prompted with up to 19 questions to determine if you would be eligible to participate in the study. Please, allow approximately **10 minutes to complete the questionnaire**.

Participation in this questionnaire is completely voluntary and you may exit the questionnaire at any time. This questionnaire will only be used to determine if you are eligible to enter the study. The data will not be published in any way and will only be used for screening purposes. Please feel free to contact our Project Coordinator Cassandra Kettenhoven at 602-827-2545 or sugarsbio@asu.edu for any questions on the study or if you prefer to complete the questionnaire on paper or over the phone.

Thank you for your interest in our study!

Q1 What is your gender?

- ❍ Male (1)
- ❍ Female (2)

Q2 Please select your age group:

- ❍ 18-30 years of age (1)
- ❍ 31-43 years of age (2)
- ❍ 44-56 years of age (3)
- ❍ 57-70 years of age (4)
- ❍ None of the above (5)

If answer is None of the above (5), then END OF SURVEY.

Q3 Zip Code of residence over the next 3 months:

Q4 Do you use tobacco products (e.g., cigarettes, chewing tobacco, cigars)?

- ❍ Yes (1)
- ❍ No (2)

If answer is YES, then END OF SURVEY.

Answer If: What is your gender? Female Is Selected

Q5 Are you pregnant or planning on becoming pregnant in the next 15 weeks?
- Yes (1)
- No (2)

If answer is YES, then END OF SURVEY.

Answer If: What is your gender? Female Is Selected
Q6 Are you currently breastfeeding?
- Yes (1)
- No (2)

If answer is YES, then END OF SURVEY.

Q7 Have you participated in any diet-related research study over the past 4 months?
- Yes (1)
- No (2)
- Unsure (3)

If answer is YES, then END OF SURVEY.

Q8 Are you currently trying to lose weight or have you been trying to lose weight at any point over the past 4 months?
- Yes (1)
- No (2)

If answer is YES, then END OF SURVEY.
Q9 Do you currently take supplements (vitamins, minerals, herbal supplements, etc.)?

❍ Yes (1)

❍ No (2)

Answer If: Do you currently take supplements (vitamins, minerals, herbal supplements, etc.)? Yes Is Selected

Q10 Would you be willing to restrict supplement use during the 10-week study period?

❍ Yes (1)

❍ No (2)

If answer is NO, then END OF SURVEY.

Q11 Do you have a refrigerator and freezer at your residence to store food?

❍ Yes (1)

❍ No (2)

If answer is NO, then END OF SURVEY.

Q12 Has a doctor every told you that you have any of the following conditions?

	Yes (1)	No (2)
Kidney Disease (1)	❍	❍
Bladder Disorder/Urinary Incontinence (2)	❍	❍
Type 2 Diabetes (3)	❍	❍
Autoimmune Diseases (e.g., Type 1 Diabetes, Inflammatory bowel disease, etc.) (4)	❍	❍
Celiac Disease (5)	❍	❍
Stomach Disorder (e.g., ulcers, GI bleeding) (6)	❍	❍
Heart Disease (7)	❍	❍
Thyroid Problem (8)	❍	❍
Cancer	❍	❍
Liver Disease (9)	❍	❍
High Blood Pressure (10)	❍	❍
Other Chronic Condition(s) (11)	❍	❍

Answer If: Has a doctor every told you that you have any of the following conditions? Autoimmune Diseases (i.e., Type 1 Diabetes, Inflammatory bowel disease, etc.) - Yes Is Selected

Q13 Please specify which autoimmune disorder, if known (if unknown, please write unknown):

Answer If: Has a doctor every told you that you have any of the following conditions? Stomach Disorder (e.g., ulcers, GI bleeding) - Yes Is Selected

Q14 Please specify which stomach disorder, if known (if unknown, please write unknown):

Answer If: Has a doctor every told you that you have any of the following conditions? Other Chronic Conditions - Yes Is Selected

Q15 Please specify which other chronic condition(s), if known (if unknown, please write unknown):

Q16 Have you taken any medications, including sulfonamides (e.g., Azulfidine, Diamox, Sequels, Sulfazine, Truxazole), acetaminophen (e.g., Tylenol, Acephen, Anacin, Feverall), Furosemide (Lasix, Furocot), painkillers, aspirin, steroids, birth control, etc. (prescribed or over the counter) over the last 4 weeks?

❍ Yes (1)

❍ No (2)

Display This Question if: Have you taken any medications, including sulfonamides (e.g., Azulfidine, Diamox, Sequels, Sulfazine, Truxazole), acetaminophen (e.g., Tylenol, Acephen, Anacin, Feverall), Furosemide (Lasix, Furoco...)- Yes Is Selected

Q17 If so, please list:

	Medication name and Brand (1)	Frequency (2)	Dose (3)
Rx/OTC 1 (1)			
Rx/OTC 2 (2)			
Rx/OTC 3 (3)			
Rx/OTC 4 (4)			
Rx/OTC 5 (5)			

Q18 Are you on any kind of dietary restriction due to a medical condition? (e.g., inflammatory bowel disease, celiac disease, etc.)

❍ Yes (1)

❍ No (2)

Answer If: Are you on any kind of dietary restriction due to a medical condition? (e.g., inflammatory bowel disease, celiac disease, etc.) Yes Is Selected

Q19 Please give details to the dietary restriction here:

____

____

Q20 Please provide your height:

Feet (1) ________

Inches (2) ________

Q21 Please provide your weight in pounds:

Pounds (1) _________

Q22 Have you ever experienced an allergic reaction to sunscreen, amino benzoate potassium (POTABA) or para-amino benzoic acid (PABA)?

- ❍ Yes (1)
- ❍ No (2)

If answer is YES, then END OF SURVEY.

(END OF SURVEY message)

Thank you for taking the time to complete the questionnaire. Unfortunately, based on the answers you have provided you are not, at this point, a candidate for this study. The answers you have provided will not be retained under any circumstances.

After this message is displayed the participant will be presented with an 'exit survey' link.

The following question, which asks about contact information will only be displayed if the respondent is eligible to participate, i.e., has not been skipped to the end of the screening questionnaire after answering any of the 7 exclusion questions. Only respondents who may be eligible to participate in the study will be asked to provide identifying information.

Thank you for filling out the questionnaire. Based on your answers, you may be eligible to take part in this study. Please provide your contact information, so we can tell you more about the study, and schedule a study visit, if you agree to participate. The study will take place at the Arizona Biomedical Collaborative Bldg.1 located on 5th St. and Van Buren in downtown Phoenix.

Q23 Contact information so we may have the opportunity to follow up with you:

Last Name (1)

First Name (2)

Email (3)

Phone (numbers only) (4)

APPENDIX D

CONSENT FORM

Consent Form

What is the purpose of this form?

The purpose of this form is to provide you (as a prospective research study participant) with information that may affect your decision as to whether or not you would want to participate in this study and to record your consent that you agree to take part in the study.

Who are the researchers?

Dr. Natasha Tasevska, an Assistant Professor at the Arizona State University (ASU) School of Nutrition and Health Promotion, is inviting you to participate in a research study that will be conducted over 11 weeks.

Why am I being invited to take part in a research study?

We are asking you to take part in this research study because we wish to recruit healthy, non-smoking volunteers 18-70 years, like yourself.

Why is this research being done?

Sugars are thought to play very important role in developing many diseases such as diabetes, cancer and cardiovascular disease. To see if this is true we need to measure the food people eat accurately and see if type of food people eat relates to the sort of diseases they develop. This study will test how accurately urine and blood biomarkers can predict the usual consumption of sugars.

How long will the research last?

While the study will run over 11 weeks, individuals will spend one month actively participating in the proposed activities.

How many people will be studied?

We plan to recruit 107 people in this research study.

What happens if I say yes, I want to be in this research?

It is up to you to decide whether or not to participate. If you decide to take part in the study:

- A **screening fasting blood sample** will be taken to check your plasma glucose and HbA1c levels. If your fasting blood glucose <100 mg/dl and HbA1c <5.7%, you will be scheduled for a baseline visit.
- **Your body weight and height will be measured.**
- **You will complete a questionnaire** with questions on your demographics, lifestyle habits, and personal medical history.
- **You will record all the foods and drinks you consume over two weeks**. For that purpose, you will be given a food diary in which you will find set of instructions to help you record your diet, and measuring cups, spoons, and a food model booklet to help you record quantities. Following each week, you will be invited to meet with our Research Kitchen Coordinator and Chef to discuss what you have recorded in your food diary and help us gather more information.

- A week after you have completed the 2-wk food diary, **you will participate in a 15-day feeding study**. During the feeding period, you will be provided with all your food on a daily basis. This is the food that you would usually eat, which we have purchased and prepared for you based on the food diaries you kept over the previous 2 weeks. You will come to our kitchen daily Monday-Friday where you will eat your breakfast or lunch and then collect your dinner, snacks and breakfast or lunch for the following day. On Fridays, you will collect your food for the entire weekend. We will provide you with cooler bags on wheels to ease the transport of meals to your home. You will be free to eat as much as you like from the food prepared for you, and you will NOT be allowed to consume any foods or drinks prepared outside of our kitchen, besides water, alcohol, and black coffee and tea (no added sugar, sweetener, milk, creamer, etc.). If you drink alcohol, you will record the type and amount consumed; you are allowed to drink wine, beer or spirits (i.e., hard liquor, such as whisky, vodka, tequila, gin, etc.) ONLY. Please note that any alcohol beverages that contain added sugars, fruits, cream, spices, herbs, flowers or nuts, such as liqueurs (e.g., Grand Marnier, schnapps) or cocktails are not allowed. We ask you to keep your intake of coffee and tea consistent throughout the 15-day feeding study. You will keep the unconsumed food/drinks in the respective container/bottle and return them to the metabolic kitchen on your next visit. Please note that no one else is allowed to eat the leftovers, and you have to return all leftovers to the metabolic kitchen, so we can calculate exactly how much food you have consumed.
- You will **collect nine breath samples during the 15-day feeding study** (three samples per day on three randomly selected days; on the breath collections days, you will collect one breath sample before breakfast, and two samples at randomly selected time points during the day).
- **We will collect 3 blood samples from you:** before and at the end of the 15-day feeding study and 5 weeks later.
- **You will collect 24-hour urine every other day during the 15-day feeding study (8 in total).** On two urine collection days, you will collect each of your urine voids in a separate container. We will give you a trolley bag for carrying urine bottles when away from home. To alleviate your burden, we will organize a pick-up service to collect the 24-h urine from your home the morning after the urine collection day (including weekend and holiday). In order to determine whether the collections are complete, you will be requested to take a capsule of aminobenzoate potassium (POTABA) with your breakfast, lunch and dinner (three capsules per day) on the urine collection days. POTABA is commonly used as a marker for ***urine completeness in research studies***, as it is nearly completely excreted in the urine soon after taking a tablet of POTABA.

- **You will keep study logs during the 15-day feeding study**: a brief physical activity log (<5 minutes to complete), and a meal checklist daily, and a urine collection log on the urine collection days.
- **You will be asked to refrain from taking any dietary supplements** during the feeding study and until collection of the final blood sample.

Samples will be stored and may be used at a later date to see if we can find other dietary biomarkers.

Participant Timeline:

Visit Timeline	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 12
Screening Visit	Day 1							
Baseline Visit	Day 4							
Food Diary		All Days	All Days					
Meeting with Chef	Day 4		Day1	Day 1				
Feeding Study					All Days	All Days	Day 1	
24-hour Urine Collection					Day 1, 3, 5, 7	Day 2, 4, 6	Day 1	
Blood Draw†	Day 1				Day 1‡		Day 2‡	Day 1‡
Breath Sample					Randomly selected day (3x)	Randomly selected day (3x)		

† 6 ml blood.

‡ ***24 ml per blood draw (3x).***

What happens if I say yes, but I change my mind later?

Even if you say "yes" now, you are free to say "no" later, and withdraw from the study at any time. Your decision will not affect your relationship with Arizona State University or otherwise cause a loss of benefits to which you might otherwise be entitled. If you decide to leave the research, you should contact the investigator so that the investigator can notate your departure in our database. If you stop being in the research, already collected data may not be removed from the study database. If it becomes evident that you are not complying with the feeding, urine collection or blood collection protocol, the research staff may remove you from the study without your consent. If this occurs, you will only be compensated for the portions of the protocol you completed.

Is there any way being in this study could be bad for me?

There are no risks associated with the feeding portion of the study. All food safety precautionary measures will be taken to ensure safe food handling and prevention of food borne illnesses. You may experience slight pain from the blood draws (4 in total, including the blood draw at screening). Although unlikely, some bruising and/or infection can occur from the blood draws. You may be inconvenienced by collecting 24-h urines (8 in total) and by not being able to eat or drink anything prepared outside of our kitchen (except for water, alcohol, coffee and tea) during the 15-day feeding study. On the urine collection days, you will be asked to take three 102 mg capsules of POTABA, one with each main meal, as a marker for 24-h urine completeness. Only few instances of side effects, such as upset stomach, nausea, loss of appetite, fever and skin allergy (rash), have been reported following intake of POTABA, and in doses much larger than the dose in this study. If you experience these symptoms, please notify the research staff, and taking of the capsules will be discontinued. An allergic reaction to sunscreen may indicate that side effects from POTABA can occur. At screening, you have informed us that you have never experienced an allergic reaction to sunscreens.

Will I be able to obtain any of the results from the samples I provide?

Participants can electively choose to receive their data from the screening blood collection, which includes fasting blood glucose and HBA1c levels. To receive these data:

a. Participation in the study must be complete (i.e., based on the screening blood results you are not eligible to participate, you voluntarily withdraw or are removed from the study, or you complete the entire study); and

b. You must sign a Research Results Acknowledgment Statement form that states that this information does not constitute medical advice or diagnosis, and that you take responsibility for sharing this information with your physician or health care provider.

Research Results Acknowledgement Statement forms available upon request.

Will being in this study help me in any way?

If you chose to sign the Research Results Acknowledgment Statement, you will be given the results on your fasting blood glucose and HBA1c level from your screening blood collection. We cannot promise any benefits from taking part in this research to you directly. However, the potential benefit to others is large, due to long-term public health impact of this project. This study will help in determining the role of sugars in risk of obesity, cardiovascular disease, cancer, type 2 diabetes, and other chronic diseases.

What happens to the information collected for the research?

All information obtained in this study is strictly confidential unless disclosure is required by law. The results of this research study may be used in reports, presentations, and publications, but the researchers will not identify you. In order to maintain confidentiality of your records, we will assign you a participant number at study entry, which will be used on all forms, meals and specimens. Your name will not appear anywhere aside from this consent form. This form will be kept in a locked cabinet in Dr. Natasha Tasevska's office to maintain your confidentiality.

What else do I need to know?

This research is being funded by the National Institutes of Health (NIH).

If you agree to take part in this research study, we will pay you up to $599: $10/day for keeping food diary for 2 weeks, $20/day during the 15-day dietary study and an additional $159 as an incentive for completing the entire study protocol. If you agree to participate in the study, this consent does not waive any of your legal rights. However, no funds have been set aside to compensate you in the event of injury.

At the end of this research project, we will be happy to explain individual results.

Who can I talk to?

If you have questions, concerns, or complaints, or think the research has hurt you, please contact ***Natasha Tasevska, at*** Natasha.Tasevska@asu.edu or 602 827-2485 ***or Cassandra Kettenhoven, Project Coordinator, at*** Cassandra.Kettenhoven@asu.edu ***or 602-827-2545.***

If you have questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk; you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at 480-965 6788 or research.integrity@asu.edu.

Signature Block for Capable Adult

Your signature documents your permission to take part in this research.

____ __________________
Signature of participant Date

____
Printed name of participant

____ __________________
Signature of person obtaining consent Date

____
Printed name of person obtaining consent

INVESTIGATOR'S STATEMENT

"I certify that I have explained to the above individual the nature and purpose, the potential benefits and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature. These elements of Informed Consent conform to the Assurance given by Arizona State University to the Office for Human Research Protections to protect the rights of human subjects. I have provided (offered) the subject/participant a copy of this signed consent document."

______________________________ ______________
Signature of investigator Date

____
Printed name of invesitgator

Research Results Acknowledgement Statement

Read and initial each statement below and sign to request your research results

☐ I understand that test results obtained during research studies are not used for diagnostic purposes.

☐ I understand that it is my responsibility to discuss any results and follow up with my primary care physician or qualified health professional, and that neither the study investigators nor research staff will provide interpretation or care recommendations on the basis of any of the research results provided to me.

My signature below confirms the above statements and receipt of my results from participation in the research study entitled:

Investigation of Biomarkers of Sugars Intake

______________________________ ______________
Signature Date

____
Printed Name

______________________________________ ________________

Researcher collecting signature Date

____

Printed Name

APPENDIX E

ASU IRB APPROVAL

ASU Knowledge Enterprise Development

APPROVAL: EXPEDITED REVIEW

Natasha Tasevska
SNHP - Nutrition
602/827-2485
Natasha.Tasevska@asu.edu

Dear Natasha Tasevska:

On 5/22/2015 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Investigation of Biomarkers for Sugars Intake – A Controlled Feeding Study
Investigator:	Natasha Tasevska
IRB ID:	STUDY00002695
Category of review:	(3) Noninvasive biological specimens, (2)(a) Blood samples from healthy, non-pregnant adults, (4) Noninvasive procedures, (7)(b) Social science methods, (7)(a) Behavioral research
Funding:	Name: NCI: National Cancer Institute, Grant Office ID: FP00001446 , Funding Source ID: 1R01CA197902-01
Grant Title:	FP00001446 ;
Grant ID:	FP00001446 ;
Documents Reviewed:	• Appendix 7, Category: Participant materials (specific directions for them); • Appendix 12 - Consent Form, Category: Consent Form; • Appendix 3 - Screening Q, Category: Recruitment Materials; • Appendix 6, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Appendix 7a, Category: Participant materials (specific directions for them); • Appendix 11, Category: Measures (Survey questions/Interview questions /interview guides/focus

	group questions); • Appendix 10, Category: Other (to reflect anything not captured above); • Appendix 4, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Appendix 2 - Information Sheet, Category: Recruitment Materials; • FP 1446 Tasevska FP.pdf, Category: Sponsor Attachment; • Sugars Biomarkers Protocol, Category: IRB Protocol; • Appendix 1 - Study Advertisement, Category: Recruitment Materials; • Appendix 9, Category: Other (to reflect anything not captured above); • Appendix 8a, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Appendix 5, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • IRB Exemption letter.pdf, Category: Off-site authorizations (school permission, other IRB approvals, Tribal permission etc); • IRB clarification requested May12.pdf, Category: Other (to reflect anything not captured above); • Appendix 8, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);

The IRB approved the protocol from 5/22/2015 to 5/21/2016 inclusive. Three weeks before 5/21/2016 you are to submit a completed Continuing Review application and required attachments to request continuing approval or closure.

If continuing review approval is not granted before the expiration date of 5/21/2016 approval of this protocol expires on that date. When consent is appropriate, you must use final, watermarked versions available under the "Documents" tab in ERA-IRB.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

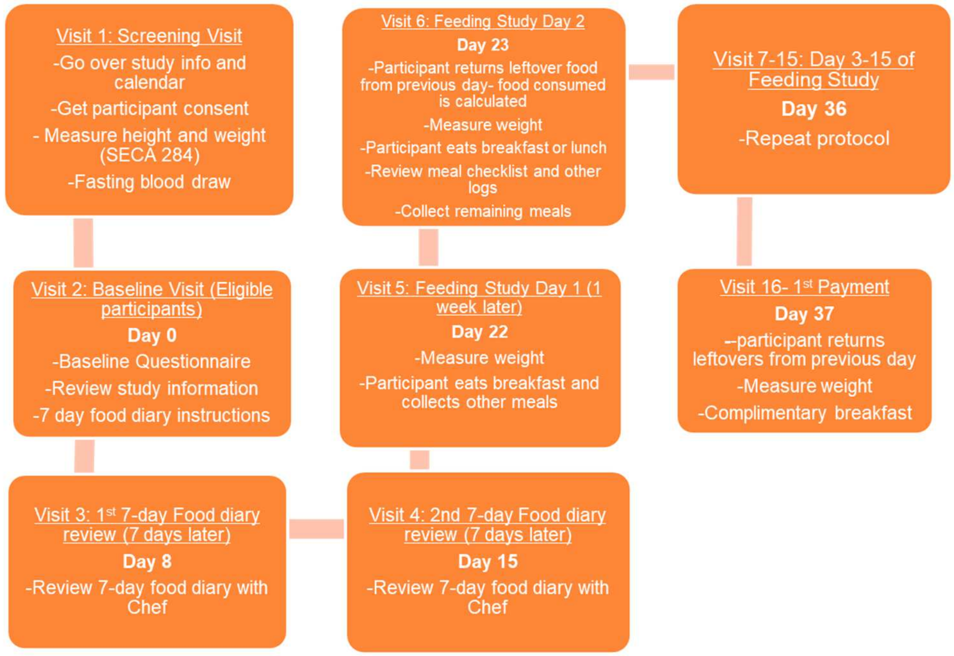
IRB Administrator

cc:

Carol Johnston
Kate Zemek

APPENDIX F

STUDY FLOW CHART


Visit 1: Screening Visit
-Go over study info and calendar
-Get participant consent
- Measure height and weight (SECA 284)
-Fasting blood draw
Visit 2: Baseline Visit (Eligible participants)
Day 0
-Baseline Questionnaire
-Review study information
-7 day food diary instructions
Visit 3: 1st 7-day Food diary review (7 days later)
Day 8
-Review 7-day food diary with Chef
Visit 4: 2nd 7-day Food diary review (7 days later)
Day 15
-Review 7-day food diary with Chef
Visit 5: Feeding Study Day 1 (1 week later)
Day 22
-Measure weight
-Participant eats breakfast and collects other meals
Visit 6: Feeding Study Day 2
Day 23
-Participant returns leftover food from previous day- food consumed is calculated
-Measure weight
-Participant eats breakfast or lunch
-Review meal checklist and other logs
-Collect remaining meals
Visit 7-15: Day 3-15 of Feeding Study
Day 36
-Repeat protocol
Visit 16- 1st Payment
Day 37
--participant returns leftovers from previous day
-Measure weight
-Complimentary breakfast

APPENDIX G

BASELINE QUESTIONNAIRE

Q1.1 Study ID: __________

Q1.2 General Information

Title
Last Name
First Name
Address
City
State
Zip Code
Email

Q1.3 Date of Birth:

|____|____| |____|____| |__|__|__|__|
MO DAY YEAR

Q1.4 Please provide contact phone numbers:

	Area Code (XXX)	XXX	XXXX
Mobile Phone			
Home Phone			
Work Phone			

Q1.5 Preferred method of contact:

- ❍ Email
- ❍ Mobile Phone
- ❍ Home Phone
- ❍ Work Phone

Q1.6 Which method do you prefer to receive your reminder notification to begin the 24-hour urine collection?

❍ Email
❍ Mobile Phone
❍ Home Phone
❍ Work Phone

Q1.7 Occupation ____________________________

Q1.8 Gender:

❍ Male
❍ Female

Q1.9 What is your current marital status?

❍ Single (never married)
❍ Living with a partner
❍ Married
❍ Divorced
❍ Widowed
❍ Other (please specify): ____________________

Q1.10 What is your education level?

❍ Less than high school
❍ High school/GED
❍ Some college
❍ Associate's Degree
❍ Bachelor's Degree
❍ Master's Degree
❍ Terminal Degree (PhD, MD, etc.)

Q1.11 What is your annual family income?

- ❍ < $15,000
- ❍ $15,000-$24,999
- ❍ $25,000-$44,999
- ❍ $45,000-$64,999
- ❍ $65,000-$84,999
- ❍ $85,000-$104,999
- ❍ >$105,000

Q1.12 What is your ethnicity?

- ❍ White/Non-Hispanic/Caucasian
- ❍ Hispanic/Latino
- ❍ African American
- ❍ Pacific Islander (Native Hawaiian, Guamanian, Samoan, Polynesian, Micronesian or Melanesian, etc.)
- ❍ Native American
- ❍ Asian
- ❍ Other: (Please specify) ____________________

YOUR LIFESTYLE

Q2.2 Have you smoked in the past?

- ❍ Yes
- ❍ No

Answer If Have you smoked in the past? Yes Is Selected

Q2.3 If yes, how often did you smoke? Choose the best answer that describes your average past smoking habits.

- ❍ Less than once a day
- ❍ Once a day
- ❍ Half a pack a day
- ❍ One pack a day
- ❍ Two packs a day
- ❍ Greater than two packs a day

Answer If Have you smoked in the past? Yes Is Selected

Q2.4 How long did you smoke?

	Please List Years and Months
	(e.g., 1 year 6 months)
Years	
Months	

Answer If Have you smoked in the past? Yes Is Selected

Q2.5 When did you quit smoking?

	Please type full month and year
	(e.g., August 2011)
Month	
Year	

Q2.6 Do you drink alcohol?

- ❍ Yes
- ❍ No

Answer If Do you drink alcohol? Yes Is Selected

Q2.7 How frequently do you drink alcohol?

- ❍ Everyday
- ❍ Twice a week
- ❍ Once a week
- ❍ Every other week
- ❍ Once a month
- ❍ Less than once a month

Answer If Do you drink alcohol? Yes Is Selected

Q2.8 On average, how many units of alcohol do you consume per week? (One unit = 12 oz of beer, 5 oz of wine, or a 1.25 oz of liquor)

Units per week: ____________

Q2.9 Do you have any special dietary requirements or food allergies?

- ❍ Yes
- ❍ No

Answer If Do you have any special dietary requirements or food allergies? Yes Is Selected

Q2.10 If you answered yes to special dietary requirements or food allergies, please specify:

APPENDIX H

USDA FOOD MODELS FOR ESTIMATING PORTION

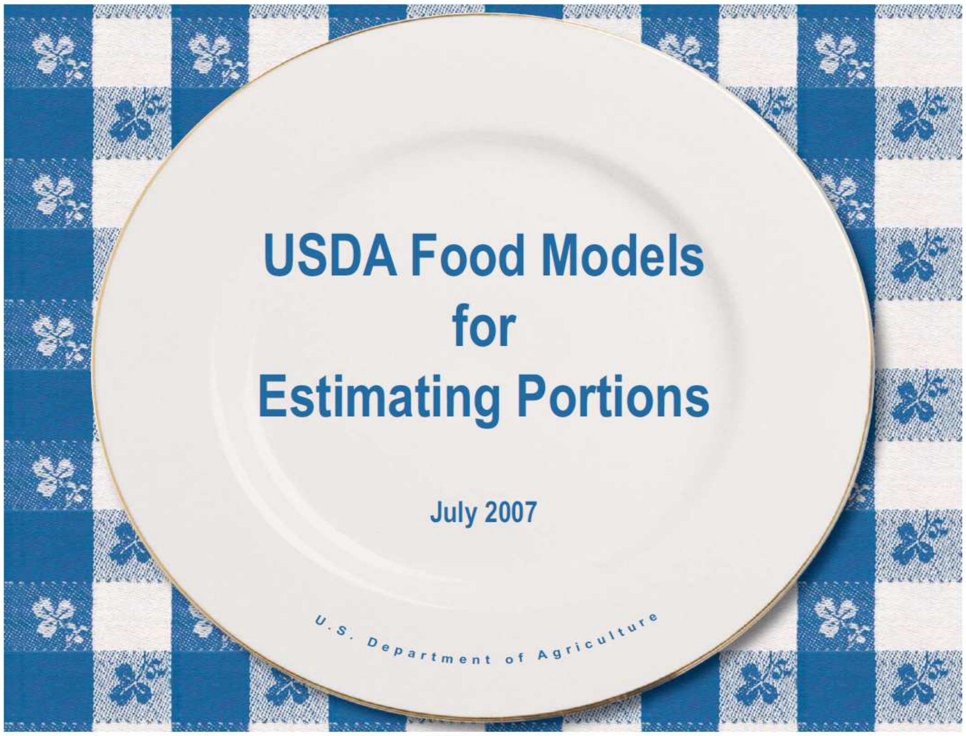
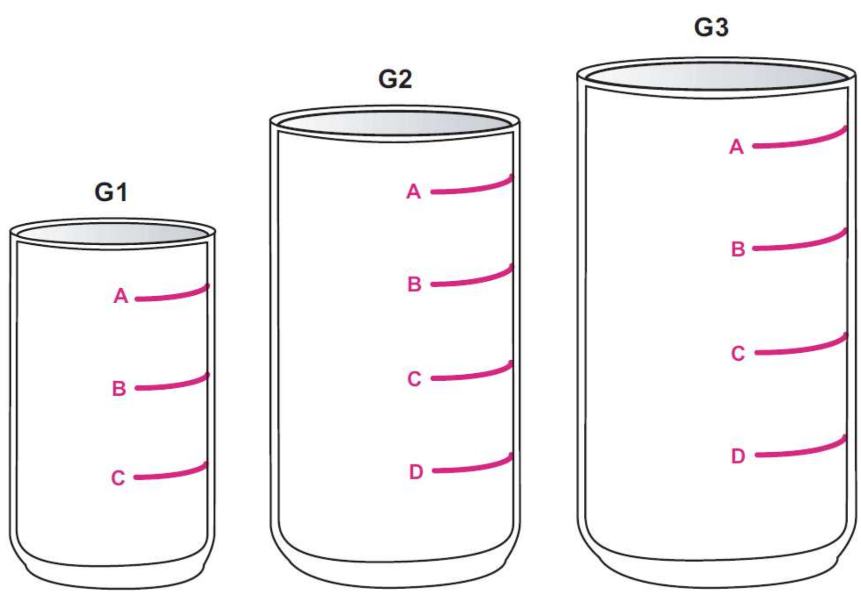


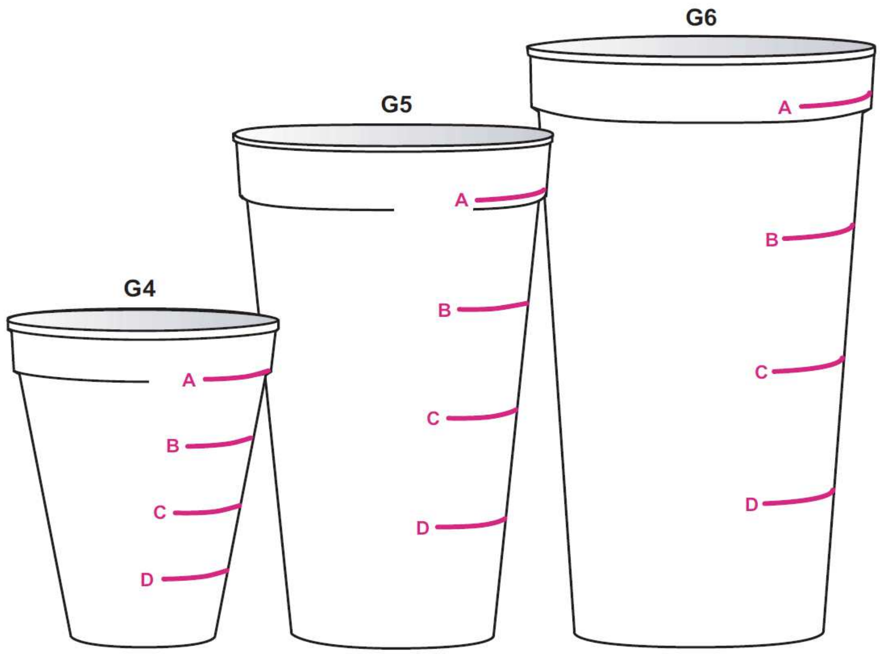
Table of Contents

The drawings in this booklet are used to describe amounts of foods and beverages.

Tab no.	Page no.	Typical Foods	Models
5	14	Biscuits Meat patties Pancakes Tortillas	CIRCLES… for round foods A set of colored circles identified as C1 - C8, ranging from 1 inch to 8 inches across. Use any circle or a size in between two circles to describe your circular food.
6	15-16	Boneless meat Brownies Cake Cornbread Lasagna Meatloaf Pizza	THICKNESS BLOCKS... for thickness or height of foods On page 15, twelve black blocks identified as T1 - T12, ranging from 1/8 inch to 1-1/2 inches high for describing the height of foods. GRID... for square and rectangular foods A 5-by-5 inch grid. To use the grid, imagine your food placed in the corner by the star. Use the numbers on the sides of the grid to describe the length of your food.
7	17-18	Cake Pie Pizza Quiche	WEDGES...for small and large triangular foods To use a wedge, imagine the tip of your food in the corner by the star. First look at the number on the baseline that is the length of your food. Then, move the arrow (or a ruler, your hand, or a straight edge) until the space between the arrow and the bottom line looks like the size of your piece. Use the letter closest to the arrow.

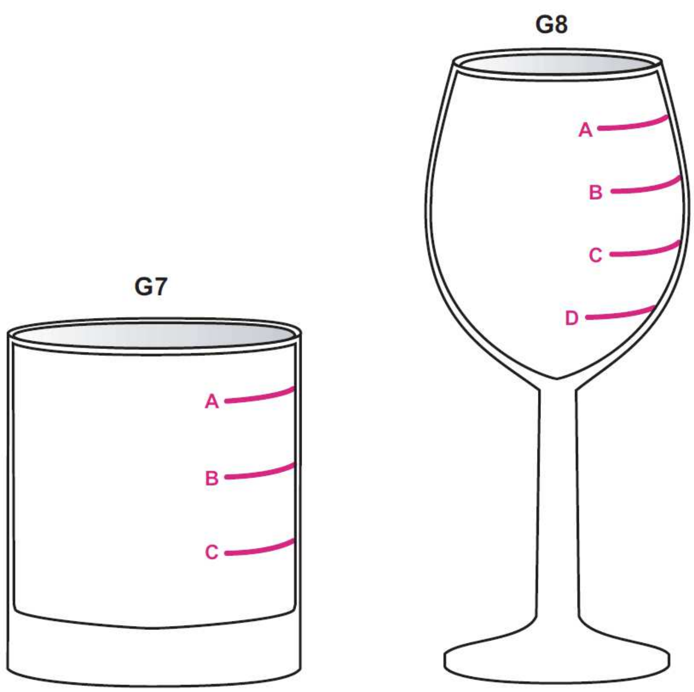


July 2007

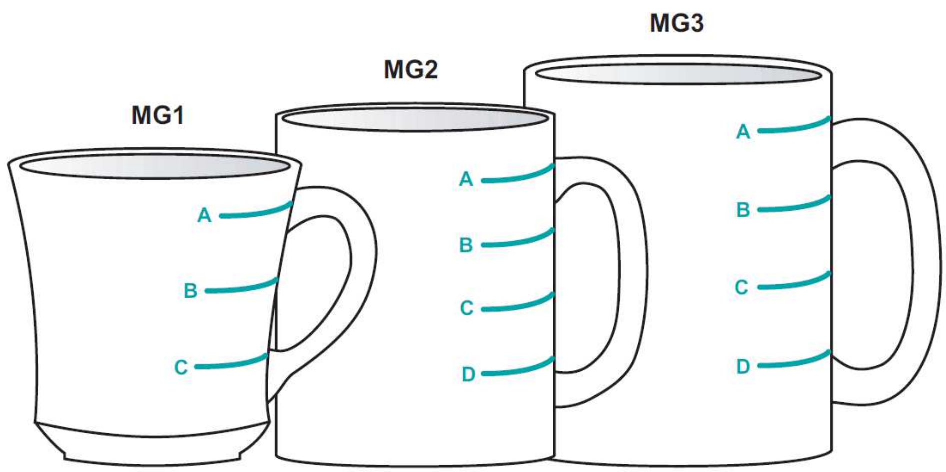


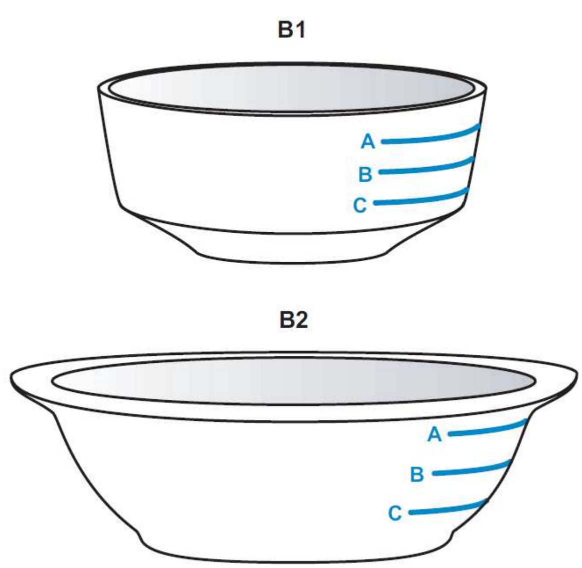
-4-

July 2007

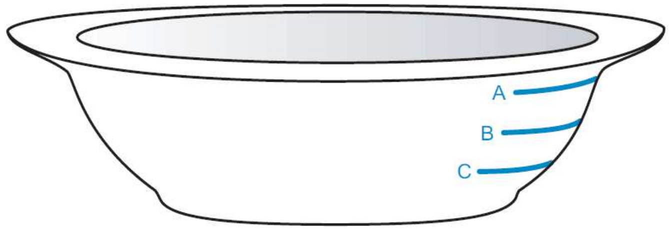


-5-

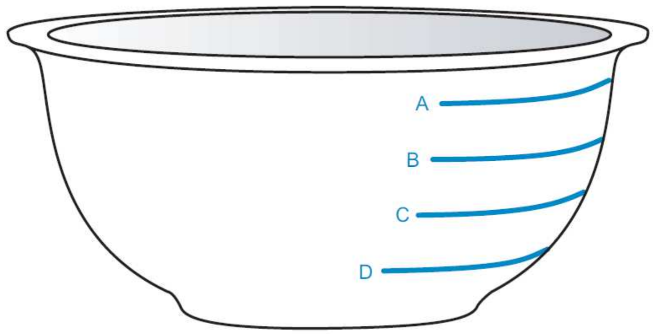

MG1
MG2
MG3
A
B
C
A
B
C
D
A
B
C
D


B1
A
B
C
B2
A
B
C

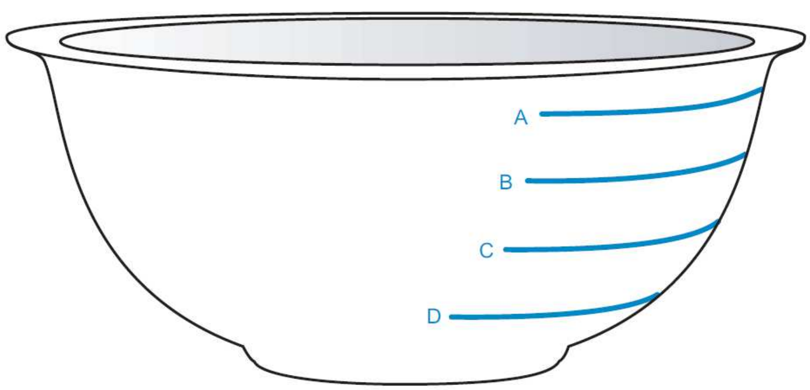
B3



B4



B5



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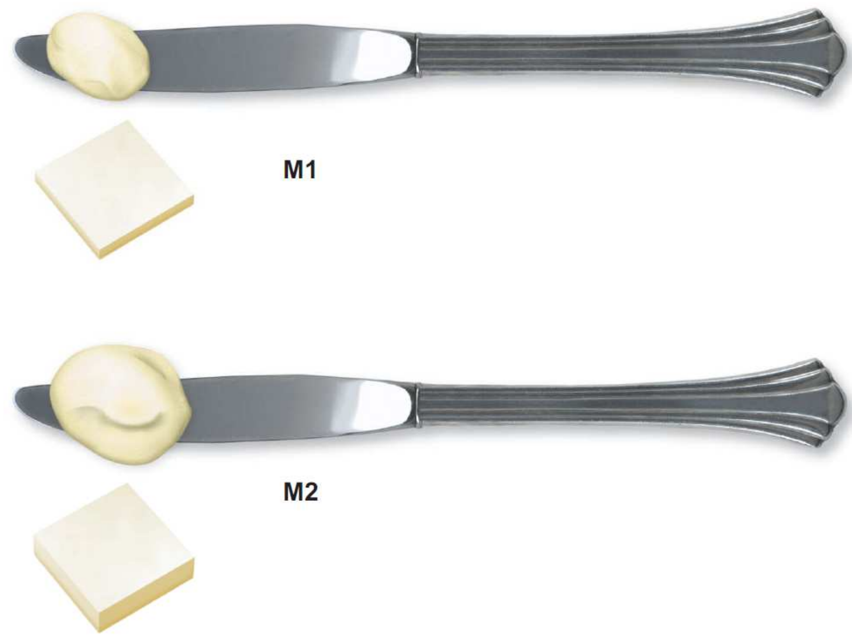
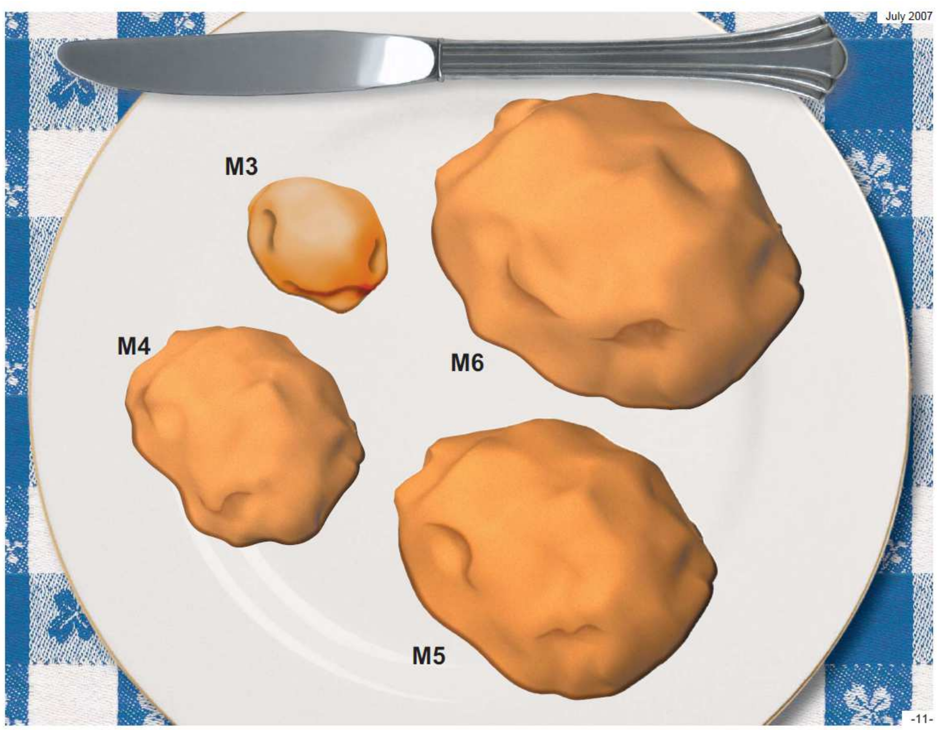
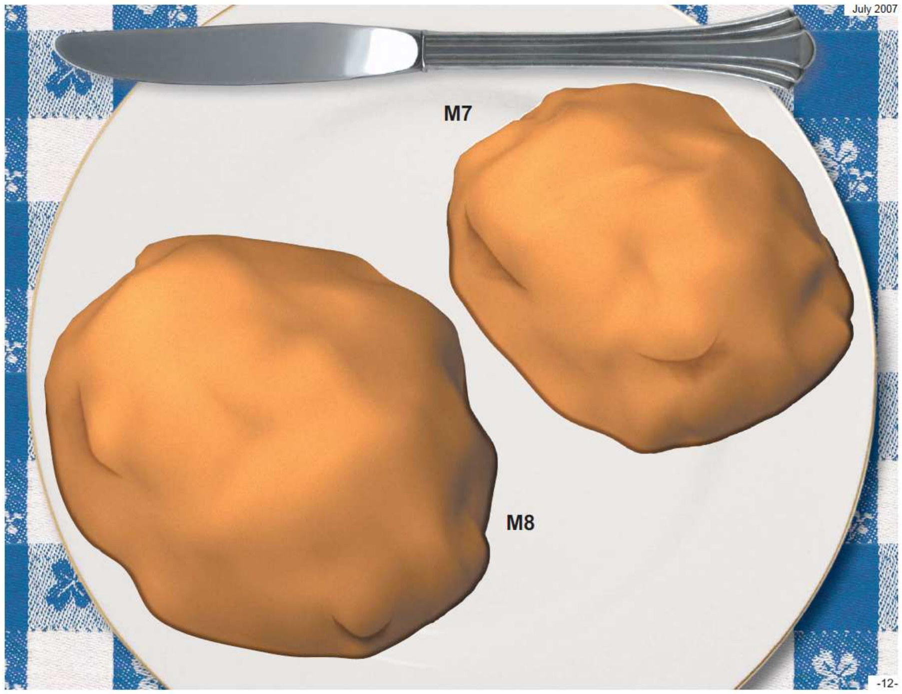


-10-

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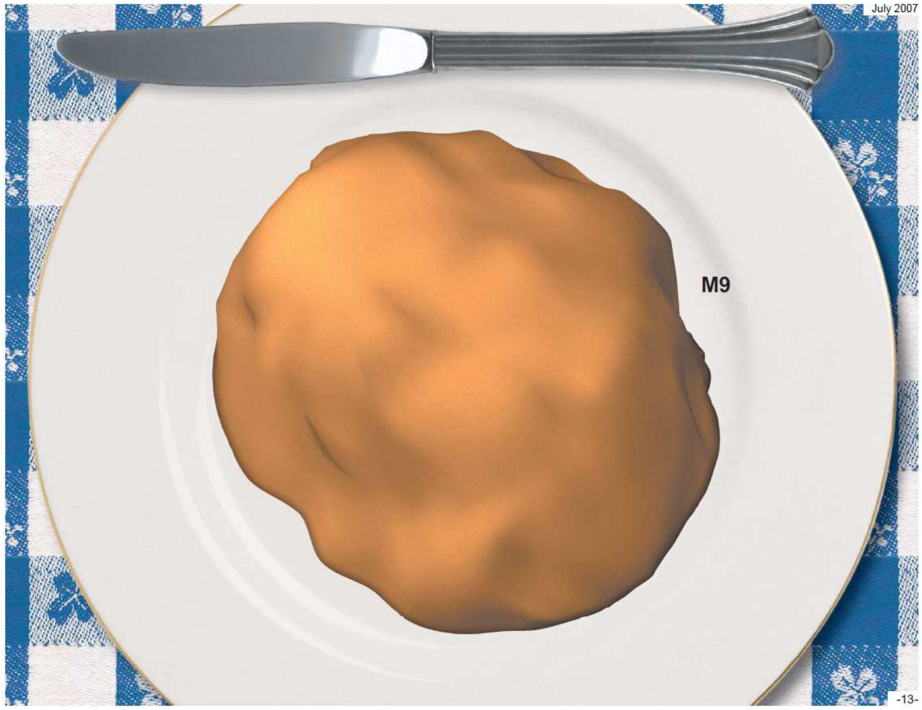
M7
M8
-12-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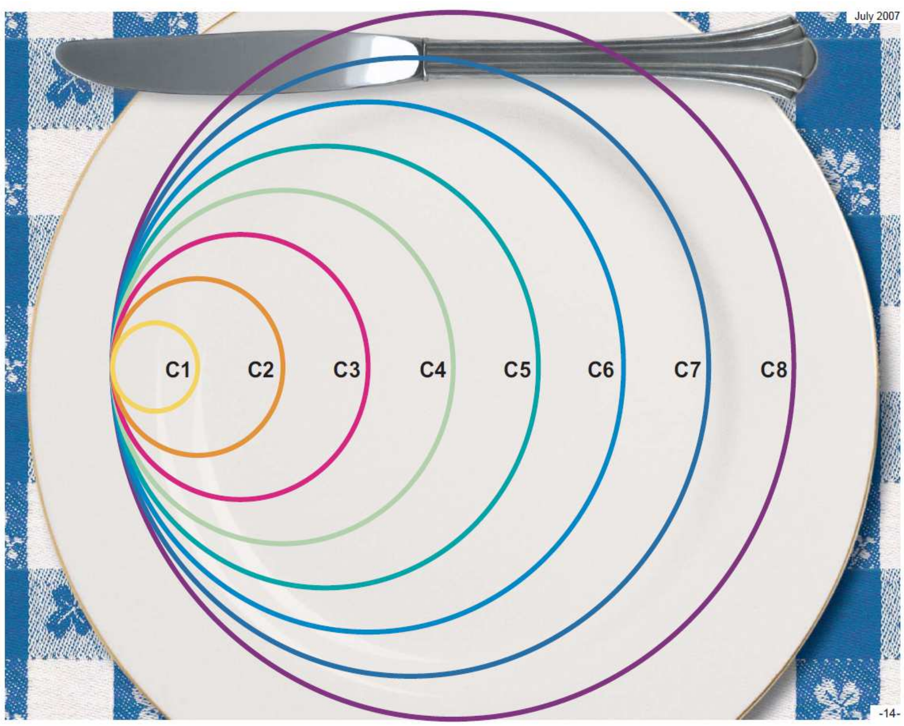
M9
-13-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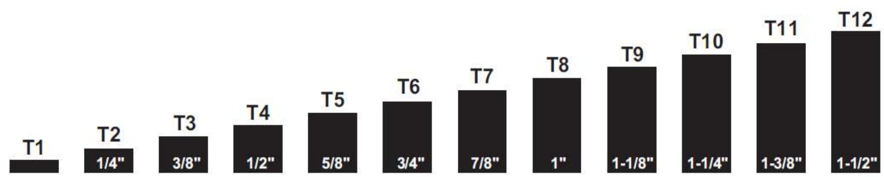
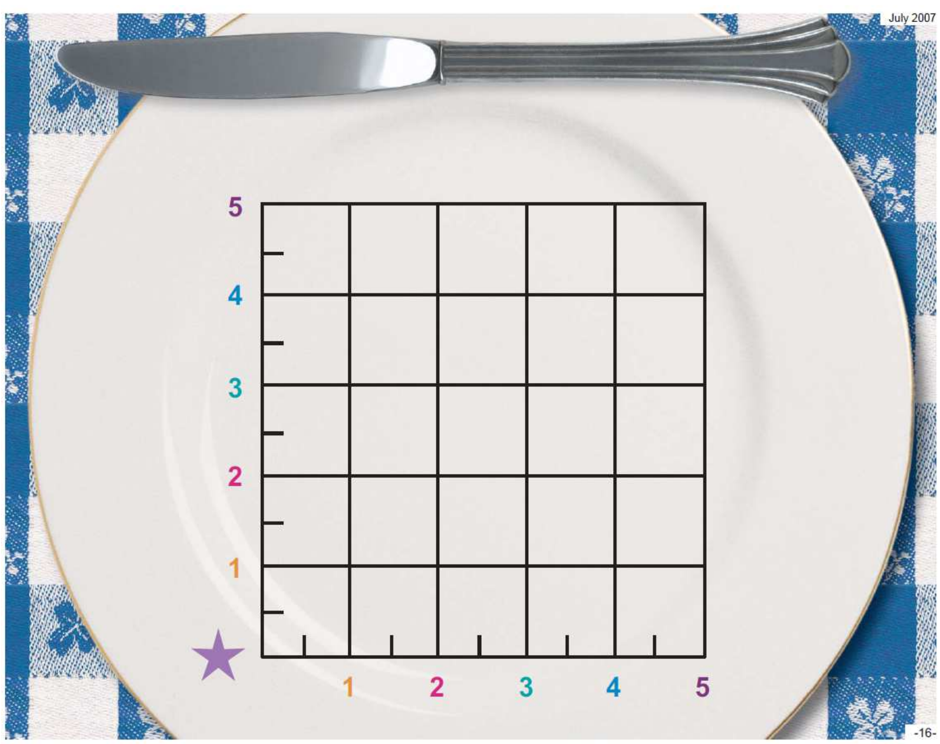
C1
C2
C3
C4
C5
C6
C7
C8
-14-


T1
T2
1/4"
T3
3/8"
T4
1/2"
T5
5/8"
T6
3/4"
T7
7/8"
T8
1"
T9
1-1/8"
T10
1-1/4"
T11
1-3/8"
T12
1-1/2"


July 2007
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4
3
2
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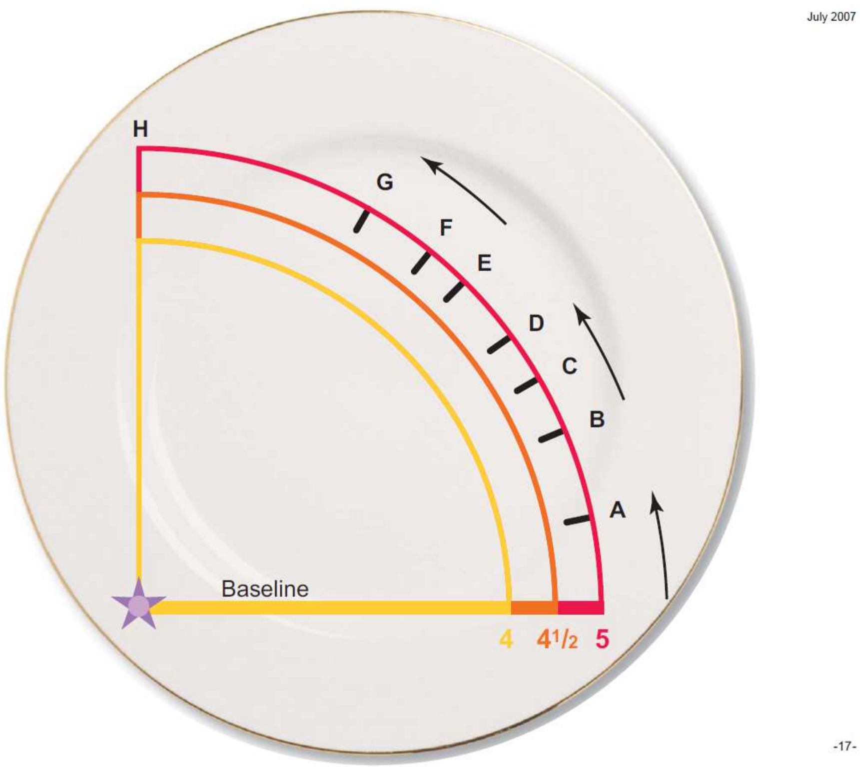
4
5
-16-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H
G
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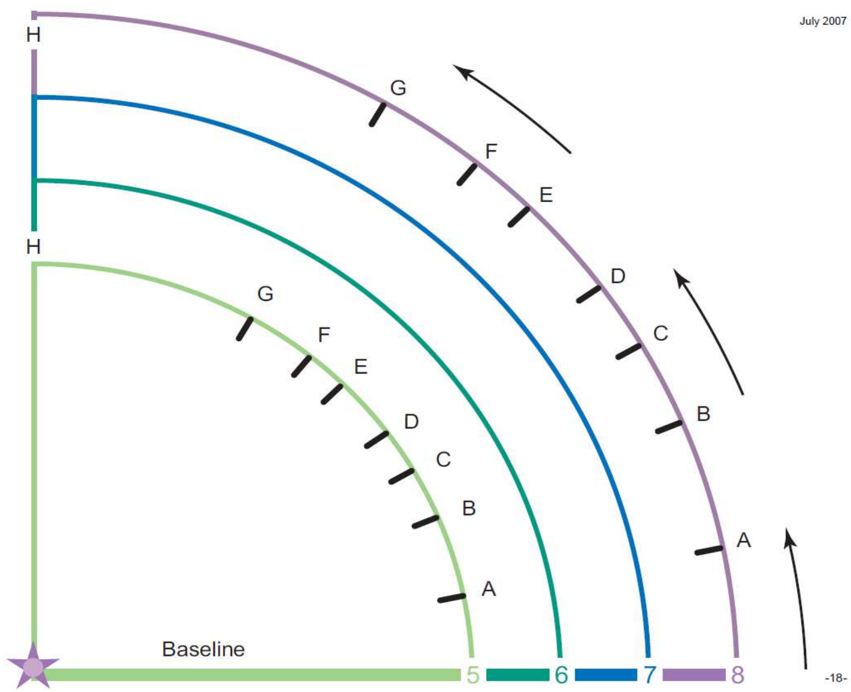
D
C
B
A
Baseline
4
4 1/2
5
-17-


July 2007
H
G
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B
A
Baseline
5
6
7
8
-18-

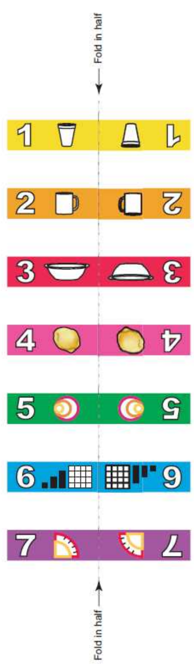
United States Department of Agriculture
Agricultural Research Service
Beltsville Human Nutrition Research Center

National Food Surveys Research Group
10300 Baltimore Avenue
Building 005, Room 102
Beltsville, MD 20705-2350

July 2007

Inserts for 1-inch clear Self-Adhesive Index Tabs

1. Cut out inserts
2. Fold in half along dotted line
3. Place in clear tabs
4. Place models back-to-back in sheet protectors, and attach tabs to pages as below:



Tab 1 - attach to page 2, 3

Tab 2 - attach to page 4, 5

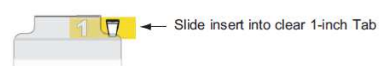
Tab 3 - attach to page 6, 7

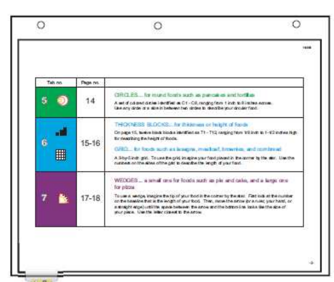
Tab 4 - attach to page 8, 9

Tab 5 - attach to page 12, 13

Tab 6 - attach to page 14, 15

Tab 7 - attach to page 16, 17





Arrows for the 5-inch and 8-inch Wedges

1. Cut out arrow around the dotted line
2. Punch small hole in center of star where indicated below
3. Punch small hole in center of purple star of wedge
4. Attach arrow to wedge with a 3/4-inch brass fastener

Punch small hole and attach at star of each wedge

APPENDIX I

MEAL CHECKLIST

ASU School of Nutrition & Health Promotion

Sugars Biomarkers Study

Study ID: ___________________________

Starting with ___________________, please track all of the meals and snacks that you eat. **Please do not eat anything not provided to you by the metabolic kitchen.** However, if you did eat something outside of the food provided to you, please record it on this checklist. Make sure to check the meals off as you eat them and not wait until the end of the day.

- You will need to consume **1 meal per day (breakfast or lunch) Monday-Friday in the metabolic kitchen.**
  - During this visit, you will pick up any remaining meals or snacks for the day and the next day's meal(s) to be consumed prior to your next visit.
- On Fridays, you will collect all of your meals and snacks for the weekend and the meals and snacks to be consumed prior to Monday's visit.
  - You will be provided with a cooler bag on wheels to ease the transportation of the meals to your home.
- You are free to eat as much as you want from the foods provided for you. **Please keep any uneaten portions in the respective container and return them to the metabolic kitchen on your next visit.**
- All meals are categorized on your Menu Plan. **Use the Menu Plan to identify which "meal" you are consuming**. Mark the correct time for each meal for example:
  - Grilled Chicken Salad is listed as "Lunch" on the menu plan, but you eat it for dinner at 7:30pm. Mark 7:30 pm next to "Lunch" on your meal checklist.
  - Pita with Hummus is listed as "afternoon snack" on the menu plan, but you eat it for your morning snack at 10am. Mark 10am next to "afternoon snack" on the meal checklist.
- If you consume one component of a meal or snack with another meal or snack please indicate that **in the notes section**. For example:
  - Chips and a Coke are listed as your afternoon snack, and you have the Coke with lunch at 12:00pm. Write in the notes section next to "Lunch" had Coke from afternoon snack.
  - Fish with rice, black beans, and a salad is listed as your dinner, and you have the rice (or some amount of rice) for afternoon snack at 3pm. Write in the notes section next to "afternoon snack" had rice from dinner (note estimated amount if different from the total amount given to you).
- Check Yes, No, and N/A according to your Menu Plan
  - No means meal was provided on Menu Plan but was not eaten
  - N/A meals meal was not provided on Menu Plan
- **In the notes section**, please specify type and amount of any **unconsumed food that you did not return to us** for any given reason:

- Forgot to eat a meal,
  - Threw any of it away,
  - Failed to return some of the food for any given reason, or
  - Someone else consumed it.
- Please record your **alcohol consumption** throughout the day. Indicate type and amount of alcohol consumed. You are allowed to drink wine, beer or spirits (i.e., hard liquor, such as whisky, vodka, tequila, gin, etc.), only. Please note that any alcohol beverages that contain added sugars, fruits, cream, spices, herbs, flowers or nuts, such as liqueurs (e.g., Grand Marnier, schnapps) or cocktails ARE NOT ALLOWED.
- Please record your **coffee and tea consumption** throughout the day. Indicate type and amount of consumed. Please keep your coffee and tea intake consistent during the feeding study. **DO NOT add** sugar, any other sweetener, milk, creamer, etc., to your coffee and tea – those will be provided by the metabolic kitchen.
- Please record any consumed food and/or beverage that was not provided by the metabolic kitchen.
- Please do not take any dietary supplements (vitamins, minerals, bioactive compounds, fatty acids, herbal supplements, etc.) during the 15-day feeding study and 5 weeks following the completion of the feeding study until the 3rd blood collection is collected!!!!

Body Weight (kg):_______65.5

Date	**Meal**	**Consumed?** (Check the appropriate box when you eat your meal)	**Time of Meal:**	**Notes -** specify type and amount of any unconsumed food that you did not return to us	**Notes -** specify variations from Menu Plan	**Alcohol Consumption** (Indicate type of drink and amount consumed in ounces)		**Tea and coffee consumption** (Indicate type of drink and amount consumed in cups)	**Did you consume any food and/or beverage that was not provided by the metabolic kitchen? (**If yes, please specify the food and the approximate amount)
						Type of drink (i.e., beer, wine, liquor)	**Ounces**		
07/12/2016 Monday	Pre Breakfast	☒ Yes ☐ No ☐ N/A	5:30 [AM] / PM						
	Breakfast	☒ Yes ☐ No ☐ N/A	7:30 [AM] / PM					1 single espresso	
	Morning Snack	☒ Yes ☐ No ☐ N/A	9:30 [AM] / PM	½ apple					
	Lunch	☒ Yes ☐ No ☐ N/A	12:00 AM/ [PM]						1 Hershey's Dark Chocolate Kiss
	Afternoon Snack	☐ Yes ☒ No ☐ N/A	___:___ AM/PM						
	Dinner	☒ Yes ☐ No ☐ N/A	6:00 AM/ [PM]		Drank Coke from Morning Snack	Red Wine	10 oz		
	Evening Snack	☒ Yes ☐ No ☐ N/A	10:00 AM/ [PM]					I cup of chamomile tea	
	Late Night Snack	☐ Yes ☐ No ☒ N/A	___:___ AM/PM						

Complete these questions the following morning:
How long did you sleep last night? (hours:minutes) __7:15_________
Yesterday, how long did you sleep/nap during the day? (if you did not, select 0) (hours:minutes) _____0:45______

APPENDIX J

MENU PLAN

SB0XX

DAY 1/ TUES	BREAKFAST	AM SNACK	LUNCH	PM SNACK	DINNER	EVENING SNACK
DAY 2/ WED	BREAKFAST	AM SNACK	LUNCH	PM SNACK	DINNER	EVENING SNACK
DAY 3/ THURS	BREAKFAST	AM SNACK	LUNCH	PM SNACK	DINNER	EVENING SNACK
DAY 4/ FRI	BREAKFAST	AM SNACK	LUNCH	PM SNACK	DINNER	EVENING SNACK

DAY 5/ SAT	BREAKFAST	AM SNACK	LUNCH	PM SNACK	DINNER	EVENING SNACK
DAY 6/ SUN	BREAKFAST	AM SNACK	LUNCH	PM SNACK	DINNER	EVENING SNACK
DAY 7/ MON	BREAKFAST	AM SNACK	LUNCH	PM SNACK	DINNER	EVENING SNACK
DAY 8/ TUES	BREAKFAST	AM SNACK	LUNCH	PM SNACK	DINNER	EVENING SNACK
DAY 9/ WED	BREAKFAST	AM SNACK	LUNCH	PM SNACK	DINNER	EVENING SNACK
DAY 10/ THUR	BREAKFAST	AM SNACK	LUNCH	PM SNACK	DINNER	EVENING SNACK

APPENDIX K

FOOD LOG BOOK

SB FOOD WEIGHT LOG (FWL) - P1

Participant ID# SB0

Put in cooler	Day: Date:	FW GIVEN	FW RETURNED	TOTAL CONSUMED	Math Chk	Put in DD	NOTES
	Pre-Breakfast						
				0 g			
				0 g			
	Breakfast						
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				#VALUE!			
	Morning Snack						
				0 g			
				0 g			
	Lunch						
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			

SB FOOD WEIGHT LOG (FWL) - P2							
Participant ID# SB0							
Put in cooler	Day: Date:	FW GIVEN	FW RETURNED	TOTAL CONSUMED	Math Chk	Put in DD	NOTES
	Afternoon Snack						
				0 g			
				0 g			
	Dinner						
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
				0 g			
	Evening Snack						
				0 g			
				0 g			
	Late Night Snack						
				0 g			
				0 g			
	Other						
				0 g			
				0 g			
				0 g			
	DAILY TOTAL	0 g	0 g	#VALUE!			

APPENDIX L

MEAL CODING CRITERIA

Meal coding criteria

1. Definitions for meals and snacks based on time of day, participant-identified meal type, and meal content criterion.

Meal (Breakfast/lunch/dinner) – eating occasion (EO) identified by participant as breakfast, lunch or dinner[1] between these times **OR** EO identified by the participant as snack while composed of meal foods and meal consists of 3 or more food groups and provides similar amount of calories to a typical meal for the participant.

Breakfast: 5:00 am - 10:59 am

Lunch: 11:00 am - 3:59 pm

Dinner: 4:00 pm – 12:00 am

Snack - EO identified by participant as snack between the times defined above **OR** an EO that occurs from 12:00 am – 4:59 am OR an **EO** identified as a meal by participant while composed of snack foods only or consists of 1-2 food groups **OR** an EO that consists of leftovers from a consumed meal and provides substantially fewer calories than a typical meal for the participant.[2]

2. Combine EO's eaten within 15 minutes of each other.

3. Designate beverage only EO's (note that smoothie is considered a beverage).

4. Combine supplements with closest EO.

---

[1] If two main meals were identified by participant or between any of defined times, based on meal content, allocate one as a meal and the other as snack if appropriate. If not (if similar in calories and/or multiple food groups) code as two meals.

[2] If two or more snacks and no main meal were identified by participant between any of defined times, allocate EO as snacks, if similar in content (see definition for snack). If not, allocate based on content (see definitions for snack and meal).

APPENDIX M

PHYSICAL ACTIVITY LOG BOOK

Physical Activity Log Book

Instructions

We would like you to keep a log of all physical activities you engage in over the next 15 days.

It's extremely important that you don't make any changes in your physical activity when you are completing the log.

You will complete a log for each day throughout the 15-day feeding study. Fill the log out at the end of the day.

You will be asked about number of popular activities you may have done each day, including home, transportation, occupational, conditioning, sports and leisure activities.

For each activity, circle *yes* if you did the activity and *no* if you did not do the activity.

For each activity you did, write down the number of hours and/or minutes you were actually moving and the time you began the activity (am or pm).

If you did an activity many times during the day, write down the total time you did that activity during the day.

If you did any activities that are not on this list, please write them on the line labeled "other," circle *yes* and write in the hours and/or minutes.

Remember to record only the hours and/or minutes you were actively engaged in the activity.

Day 1: Date ___/__/20__ Day of the Week: ___________				
Did you do this activity today?	**Yes** (circle one)	**No**	**How Long?** Hours: Minutes	Time started activity **AM or PM**
Home Activities				
Sweep, scrub floors, vacuum, washing clothes, etc	Yes	No	____:______	________ AM/PM
Carpentry	Yes	No	____:______	________ AM/PM
Gardening or Yard Work	Yes	No	____:______	________ AM/PM
Transportation				
Walk to work, school, shopping	Yes	No	____:______	________ AM/PM
Bicycle to work, school, shopping	Yes	No	____:______	________ AM/PM
Occupation				
Sitting at work	Yes	No	____:______	________ AM/PM
Standing at work	Yes	No	____:______	________ AM/PM
Walking at work	Yes	No	____:______	________ AM/PM
Lift or carry 10-20 lbs at work	Yes	No	____:______	________ AM/PM
Lift or carry 20+ lbs at work	Yes	No	____:______	________ AM/PM
Other: ______________	Yes	No	____:______	________ AM/PM
Conditioning Activities				
Aerobic Exercise, Aerobic Dance	Yes	No	____:______	________ AM/PM
Bicycling	Yes	No	____:______	________ AM/PM
Calisthenics or gymnastics	Yes	No	____:______	________ AM/PM
Jogging or running	Yes	No	____:______	________ AM/PM
Hiking with pack or in mountains	Yes	No	____:______	________ AM/PM
Martial arts (judo, karate, tai chi)	Yes	No	____:______	________ AM/PM
Rowing a boat, canoeing	Yes	No	____:______	________ AM/PM
Swimming	Yes	No	____:______	________ AM/PM
Walking for exercise	Yes	No	____:______	________ AM/PM
Weight lifting, body building	Yes	No	____:______	________ AM/PM
Other: ______________	Yes	No	____:______	________ AM/PM
Other: ______________	Yes	No	____:______	________ AM/PM
Sports Activities				
Baseball or softball	Yes	No	____:______	________ AM/PM
Basketball, European Handball	Yes	No	____:______	________ AM/PM
Surfing	Yes	No	____:______	________ AM/PM
Cross-country skiing	Yes	No	____:______	________ AM/PM
Handball, racquetball, or squash	Yes	No	____:______	________ AM/PM
Ice or roller skating, ice-hockey	Yes	No	____:______	________ AM/PM
Rugby, football	Yes	No	____:______	________ AM/PM
Soccer	Yes	No	____:______	________ AM/PM
Tennis	Yes	No	____:______	________ AM/PM
Volleyball	Yes	No	____:______	________ AM/PM
Other: ______________	Yes	No	____:______	________ AM/PM
Other: ______________	Yes	No	____:______	________ AM/PM
Leisure Activities				
Bowling	Yes	No	____:______	________ AM/PM
General Dancing	Yes	No	____:______	________ AM/PM
Golf	Yes	No	____:______	________ AM/PM
Fishing	Yes	No	____:______	________ AM/PM
Table Tennis	Yes	No	____:______	________ AM/PM
Walking for pleasure or social	Yes	No	____:______	________ AM/PM
Yoga	Yes	No	____:______	________ AM/PM
Watching television	Yes	No	____:______	________ AM/PM
Other: ______________	Yes	No	____:______	________ AM/PM
Other: ______________	Yes	No	____:______	________ AM/PM
End of Day 1				

APPENDIX N

VARIABLE DISTRIBUTION AND TRANSFORMATION TABLE

Variable	**Distribution or Transformation**
Meal frequency	ND
Snack frequency	ND
sqrt (Beverages only frequency)	sqrt
sqrt (TEI, kcal/day)	sqrt
Log 10 (Age, years)	Log10
Active MET hours	ND
Total EO frequency	ND
Total EO frequency (no beverages only)	ND
BMI	ND
Sqrt (energy, kcal)	sqrt
Log10 (Energy from breakfast, kcal)	Log10
Energy from lunch, kcal	ND
Log10 (Energy from dinner, kcal)	Log10
Sqrt (Energy from snacks, kcal)	sqrt
Sqrt (Energy from beverages only, kcal)	sqrt
Sqrt (Energy from the morning, kcal)	sqrt
Energy from the afternoon, kcal	ND
Energy from the evening, kcal	ND
Sqrt (Energy from at night, kcal)	sqrt
% energy from AS	ND
Sqrt (% energy from AS from breakfast)	sqrt
Sqrt (% energy from AS from lunch)	sqrt
Log10 (% energy from AS from dinner)	Log10
% energy from AS from snacks	ND
% energy from AS from beverages only	SD
% energy from AS from the morning	ND
Sqrt (% energy from AS from the afternoon)	sqrt
% energy from AS from the evening	ND
Sqrt (% energy from AS from at night)	sqrt
Sqrt (% breakfast energy from AS)	sqrt
Sqrt (% lunch energy from AS)	sqrt
Sqrt (% dinner energy from AS)	sqrt
% snacks energy from AS	ND
% beverages only energy from AS	SD
% morning energy from AS	ND
Sqrt (% afternoon energy from AS)	sqrt
Sqrt (% evening energy from AS)	sqrt
Sqrt (% night energy from AS	sqrt
% AS from Breakfast	ND
% AS from Lunch	ND
Sqrt (% AS from dinner)	sqrt
% AS from Snacks	ND
% AS from Beverages only	SD
% AS from the morning	ND
% AS from the afternoon	ND

% AS from the evening	ND
% AS from at night	ND
% energy from breakfast	ND
% energy from lunch	ND
% energy from dinner	ND
Sqrt (% energy from snacks)	sqrt
Sqrt (% energy from beverages only)	sqrt
% energy from the morning	ND
% energy from the afternoon	ND
% energy from the evening	ND
% energy from at night	ND

AS= Added sugars, IN=Inverse, MET= Metabolic equivalent value, ND=Normal distribution, and SD= Skewed distribution (can't be transformed)

APPENDIX O

VARIABLE DISTRIBUTION AND TRANSFORMATION TABLE (MALES)

Variable	Distribution or Transformation
Total EO frequency	ND
Meal frequency	ND
Snack frequency	ND
sqrt (Beverages only frequency)	sqrt
TEI, kcal/day	ND
Inverse (Energy from breakfast, kcal)	IN
Energy from lunch, kcal	ND
Log10 (Energy from dinner, kcal)	Log10
Energy from snacks, kcal	ND
sqrt (Energy from beverages only, kcal)	sqrt
Inverse (Energy from the morning, kcal)	IN
Energy from the afternoon, kcal	ND
Reflect sqrt (Energy from the evening, kcal)	Reflect sqrt
Energy from at night, kcal	ND
% energy from AS	ND
sqrt (% breakfast energy from AS)	sqrt
sqrt (% lunch energy from AS)	sqrt
sqrt (% dinner energy from AS)	sqrt
sqrt (% snacks energy from AS)	sqrt
sqrt (% beverages only energy from AS)	sqrt
% morning energy from AS	ND
sqrt (% afternoon energy from AS)	sqrt
Log10 (% evening energy from AS)	Log10
sqrt (% night energy from AS)	sqrt
sqrt (% AS from Breakfast)	sqrt
Log10 (% AS from Lunch)	Log10
sqrt (% AS from dinner)	sqrt
Reflect sqrt (% AS from Snacks)	Reflect sqrt
sqrt (% AS from Beverages only)	sqrt
Inverse (% AS from the morning)	IN
% AS from the afternoon	ND
sqrt (% AS from the evening)	sqrt
sqrt (% AS from at night)	sqrt
Inverse (% energy from breakfast)	IN
Inverse (% energy from lunch)	IN
% energy from dinner	SD
% energy from snacks	ND
sqrt (% energy from beverages only)	sqrt
sqrt (% energy from the morning)	sqrt
sqrt (% energy from the afternoon)	sqrt
Reflect sqrt (% energy from the evening)	Reflect sqrt
Reflect sqrt (% energy from at night)	Reflect sqrt

AS= Added sugars, IN=Inverse, ND=Normal distribution, and SD= Skewed distribution (can't be transformed)

APPENDIX P

VARIABLE DISTRIBUTION AND TRANSFORMATION TABLE (FEMALES)

Variable	Distribution or Transformation
Total EO frequency	ND
Meal frequency	ND
Snack frequency	ND
Beverages only frequency	ND
Sqrt (TEI, kcal/day)	sqrt
Energy from breakfast, kcal	ND
sqrt(Energy from lunch, kcal)	sqrt
Log10 (Energy from dinner, kcal)	Log10
Log10 (Energy from snacks, kcal)	Log10
Sqrt (Energy from beverages only, kcal)	sqrt
Sqrt (Energy from the morning, kcal)	sqrt
Energy from the afternoon, kcal	ND
Sqrt (Energy from the evening, kcal)	sqrt
Sqrt (Energy from at night, kcal)	sqrt
% energy from AS	ND
Sqrt (% breakfast energy from)	sqrt
Sqrt (% lunch energy from AS)	sqrt
% dinner energy from AS	ND
% snacks energy from AS	ND
% beverages only energy from AS	SD
Sqrt (% morning energy from AS)	sqrt
% afternoon energy from AS	ND
% evening energy from AS	ND
% night energy from AS	ND
Sqrt (% AS from Breakfast)	sqrt
% AS from Lunch	ND
Sqrt (% AS from dinner)	sqrt
Sqrt (% AS from Snacks)	sqrt
% AS from Beverages only	SD
Sqrt (% AS from the morning)	sqrt
Sqrt (% AS from the afternoon)	sqrt
Reflect sqrt (% AS from the evening)	Reflect sqrt
Reflect sqrt (% AS from at night)	Reflect sqrt
Reflect sqrt (% energy from breakfast)	Reflect sqrt
Log10 (% energy from lunch)	Log10
Inverse (% energy from dinner)	IN
Inverse (% energy from snacks)	IN
Sqrt (% energy from beverages only)	sqrt
Sqrt (% energy from the morning)	sqrt
Reflect sqrt (% energy from the afternoon)	Reflect sqrt
Sqrt (% energy from the evening)	sqrt
Log10 (% energy from at night)	Log10

AS= Added sugars, IN=Inverse, ND=Normal distribution, and SD= Skewed distribution (can't be transformed)