Eating Frequency and Relative Weight in Children and Adolescents

A Thesis

Presented to the Faculty

of

The Friedman School of Nutrition Science and Policy

By,

Erin Whitney Evans MS, RD

In partial fulfillment of the requirements for the

Degree of Doctor of Philosophy

Advisor: Aviva Must, Ph.D.

Tufts University

August 2013

Acknowledgements

One of the joys of completing my thesis is to look back over the last four years and acknowledge all those who have helped and supported me through this long but fulfilling journey.

My sincerest thanks go to my thesis advisor, Dr. Aviva Must. Thank you, Dr. Aviva, for taking me on as a student, for providing me with so many opportunities here at Tufts and beyond, and for helping me to develop professionally. I am eternally grateful for your guidance and for your support of me as both a student and a new mom. You are an incredible role model for a woman starting out in academia. I would also like to express my gratitude to members of my thesis committee; Dr. Jerry Dallal, Dr. Paul Jacques, and Dr. Jennifer Sacheck. Thank you for all of the time and effort you have dedicated to my training. I would like to offer a special thank you to Jen, for allowing me to carry out my thesis research within the Daily D Health Study.

There are also several members of the Tufts community to whom I am very grateful. Thank you to Dr. Jeanne Goldberg, for your advice and support, to Dr. Fang Fang Zhang, for teaching me so very much in my directed study, to Dr. Martha Morris, for providing help with my NHANES analysis, to Dr. Misha Eliasziw, for being an incredible resource and teacher, and to Ken Chui, for entertaining any and all statistical inquiries. Thank you also to the Daily D Health Study team and to the Registered Dietitians who helped me collect data. To Dr. Adela Hruby, Dr. David Tybor, and to the doctoral students in the John Hancock Research Center, thank you for your support and friendship along the way. I would particularly like to thank Kristie Usher Hubbard for sharing this adventure with me. The future is brighter because of you!

I would also like to thank Dr. Linda Bandini, Dr. Sarah Anderson, and Dr. Kendrin Sonneville who inspired me to pursue this track and provided guidance along the way.

Finally, and most importantly, I would like to thank my family, without whom I never would have pursued a doctoral degree. To my parents, Jim and Sheri Evans, you have supported me in every way possible and given me every opportunity to succeed in life. Thank you for all of your love! To my husband, Jason Brupbacher, thank you for encouraging me to take this path. You bring me balance through your unyielding support, humor and love. To my sweet Tory B., thank you for providing me with perspective during my thesis. You are by far the best gift, and I am so grateful to be your mom. To my brother and sister, my in-laws, and my closest friends, thank you for all of your support and for never allowing me to take myself too seriously. I am very blessed to have you all in my life.

Abstract

Identifying points of intervention to reduce the burden of childhood obesity is critical. Despite concurrent trends of increased childhood obesity prevalence and increased eating frequency, the role of eating frequency in excess childhood weight gain is not well understood. To clarify this relationship, we examined the cross-sectional and prospective relationships of eating frequency with relative weight in children using data from the National Health and Nutrition Examination Survey (NHANES) 2005-2010 and the Daily D diet sub-study. We also explored the relationships of eating frequency with total energy intake, diet quality, and television (TV) viewing as possible pathways by which the eating frequency may affect relative weight in children.

In cross-sectional analyses using data from 9,713 children, ages 2-18 years, who participated in NHANES 2005-2010, we observed that the relationships of eating frequency with weight status, total energy intake and diet quality differed among pediatric life stage groups. Unexpectedly, we found that eating frequency was associated with lower odds of being obese in both elementary school-age (6-11 years) and adolescent (12-18 years) participants, despite the observed positive association between eating frequency and total energy intake. Also inconsistent with our hypothesis, we found that eating frequency was associated with better diet quality, as measured by the Healthy Eating Index-2005 (HEI-2005), in both older age groups.

Using prospective data from the Daily D study, a low-income, racially and ethnically diverse sample of 176 school-age children, ages 9-15 years, we were able to compare the cross-sectional and prospective relationships of eating frequency with relative weight. At baseline, we observed a statistically significant and inverse cross-sectional association between eating frequency and BMI z-score (BMIz); however, the association between eating frequency and 6-month change in BMIz was statistically significant and positive. Similar to our findings in NHANES, eating frequency was statistically significantly and positively associated with total energy intake. With respect to diet quality, snacking behavior was positively associated with diet quality in elementary school-age participants and inversely associated with diet quality in adolescents.

Finally, in a cross-sectional analysis of the relationship between TV viewing and eating frequency in children ages 6-11 years who participated in NHANES, 2005-2010, each additional reported hour of daily TV viewing was statistically significantly associated with increased odds of being overweight or obese and lower total diet quality. The relationships of TV viewing with eating frequency and with total energy intake, in separate models, however, were not statistically significant.

The observed inverse cross-sectional relationship of eating frequency with relative weight and positive association with total energy intake is paradoxical. However, when considered along with the observed positive prospective association between eating frequency change in BMIz, we conclude that the inverse association between eating frequency with relative weight is likely an artifact of the cross-

sectional study design. More specifically, the prospective findings support that residual confounding, reverse causation, and/or biased dietary recall may account for the inverse cross-sectional relationship. The present research highlights the need for further prospective work to assess the relationship between usual eating frequency and long-term weight gain in children.

Table of Contents

List of Tables and Figures

Chapter 3:

Chapter 4:

Chapter 5:

Chapter 5: (Continued)

Chapter 6:

Appendix A:

Appendix B:

Abbreviations:

AAP: American Academy of Pediatrics

AMPM: Automated Multiple Pass Method

BMI: Body Mass Index

BMIz: BMI z-score

CDC: Centers for Disease Control and Prevention

CFSII: Continuing Food Survey of Intake in Individuals

CNPP: Center for Nutrition Policy and Promotion

DGA: Dietary Guidelines for Americans

EER: Estimated Energy Requirements

HEI-2005: Healthy Eating Index, 2005

MEC: Mobile Examination Center

NCHS: National Center for Health Statistics

NDSR: Nutrition Data System for Research

NHANES: National Health and Nutrition Examination Survey

NHLBI: National Heart, Lunch and Blood Institute

PIR: Poverty-to-Income Ratio

SES: Socio-Economic Status

SOFAAS: Solid Fat, Alcohol, and Added Sugars

SSB: Sugar-Sweetened Beverages

TV: Television

USDA: United States Department of Agriculture

Chapter One

Introduction

Chapter One: Introduction

Childhood overweight and obesity have reached epidemic proportions in the United States. Estimates from the National Health and Nutrition Examination Survey (NHANES) 2009-2010 suggest that one-third of children are overweight or obese, and ethnic minorities, particularly those of low socioeconomic status (SES), are disproportionately affected (1). Physiologically, obesity results from an imbalance between energy consumed and energy expended, such that prevention hinges on eating less and being more physically active. In the current obesogenic environment, however, children consume diets low in fruits, vegetables, and whole grains and high in low-nutrient, energy dense foods (2), physical activity levels are well below recommendations (3), and total screen-time estimates are more than three times the two hour limit recommended by the American Academy of Pediatrics (AAP) (4, 5).

Nationally representative data from the 1970's to the 2000's show that as childhood obesity prevalence has increased, so have eating frequency (6) and total energy intake (7). Whereas several contributors to childhood obesity are well established, the role of eating frequency in excess childhood weight gain remains unclear. This is largely due to inconsistent findings across cross-sectional and prospective studies, the cause of which is not readily understood. Inconsistencies are attributable to methodological limitations in cross-sectional studies, a shortage of prospective work, and variations in the definition of eating occasions and dietary assessment methods used across studies. As a result of the equivocal literature, parents, schools and clinicians are without clear guidance as to an ideal eating frequency to minimize childhood obesity risk. Thorough understanding of how eating frequency affects relative weight in childhood is critical to both preventing and treating obesity.

Study Populations and Methods Overview:

National Health and Nutrition Examination Survey, 2005-2010

The National Health Survey Act of 1956 provided legislation for a continuing survey designed to monitor the effects of illness and disability in the United States (8). In compliance with this legislative act, the National Center for Health Statistics (NCHS) conducted its first National Health Examination Survey (NHES I) from 1960 to 1962. Through several subsequent cycles and a refocus on nutrition and its relationship to health status, NHES I evolved into the continuous National Health and Nutrition Examination Survey (NHANES). Continuous NHANES is a program of studies that evaluates the nutritional status and health of adults and children in the United States. Through a complex, multistage, probability sampling design, NCHS annually surveys approximately 7,000 citizens to yield samples that are representative of the civilian, non-institutionalized US population (9).

As part of the NHANES protocol, participants and/or eligible proxies complete an in-person health interview as well as a physical exam and laboratory studies within the Mobile Examination Center (MEC). The health interview includes demographic, socioeconomic, dietary, and health-related questions. The MEC exam includes medical, dental, and physiological measurements, as well as laboratory tests (9). Height and weight are measured for each eligible participant during the MEC exam. Height is measured in centimeters using a stadiometer, and weight is measured in kilograms using a digital scale and (10). BMI (kg/m^2) is calculated for each participant from height and weight measurements. Centers for Disease Control and Prevention (CDC) age- and sex-specific BMI growth charts were used to determine weight status f (11, 12).

Diet is measured as part of the survey via two non-consecutive, repeat 24-hour dietary recalls. The first recall is collected in-person at the time of the MEC exam, and the second recall is collected 3-10 days later by telephone (13). Both recalls are collected by a trained interviewer using the United States Department of Agriculture (USDA) Automated Multiple Pass Method (AMPM) (13). The AMPM has been validated for energy using the doubly-labeled water technique (14). Parents or guardians report dietary intake for children ages 2-5 years, parent- or guardian-assisted interviews are conducted with children ages 6-11 years, and adolescents, ages 12-18 years, report their own intake.

We have analyzed dietary and anthropometric data from children ages 2-18 years who participated in NHANES 2005-2006, 2007-2008 and 2009-2010. The sample for these analyses included children aged 2-18 years with complete anthropometric data and a complete, reliable, in-person 24-hour recall. The final sample included 9,876 children. A total of 1,015 participants ages 2 to 18 years were not included in this analysis because they were missing both anthropometric and dietary data (41%), missing anthropometric data only (13%), missing dietary data only (28%), or provided unreliable 24-hour recall data (18%). The Institutional Review Board of Tufts University approved this study as non-human subjects research.

Daily D Diet Sub-study

The Daily D diet sub-study was a supplement to the Daily D Study, a randomized trial designed to determine the appropriate level of vitamin D supplementation needed to prevent serum vitamin D inadequacy in school-age children. Participants were recruited from five public schools in three communities in the greater Boston, Massachusetts area: Everett, Malden and Somerville. A total of 312 participants, ages 9 to 15 years, enrolled in the trial, which was comprised of four study visits from October 2011 to December 2012: baseline, 3-months, 6-months, and 1-year. Other than providing a vitamin D supplement to all participants, the trial's protocol did not include any dietary intervention.

At the 3-month study visit, 183 participants were recruited from four of the five schools into the diet sub-study. Recruitment did not occur at the fifth school due to logistical constraints. Students were ineligible for the Daily D Study if they were currently taking vitamin D or multi-vitamin supplements, taking oral glucocorticoids, or had rickets, cystic fibrosis, kidney disease, sarcoidosis, irritable bowel syndrome, epilepsy, or HIV/AIDS. Participation required complete weight and height measurements at baseline and willingness to complete two 24-hour diet recalls. Parental informed consent and child assent was obtained for both the diet sub-study.

Body mass index (BMI = weight (kg) / height (m^2)), which is frequently used as a surrogate for adiposity in children (15), was calculated from height and weight measurements collected at baseline, 6 months, and 1 year. Height was measured without shoes using a portable stadiometer (Model 214, Seca Weighing and Measuring Systems, Hanover, MD) and recorded to the closest 1/8th inch. Weight was measured without shoes in light clothing on a portable balance beam scale (Healthometer, Boca Raton, FL) and recorded to the closest 1/4 pound. All measures were taken in triplicate. BMI measurements were converted to BMI z-scores (BMIz) relative to the Centers for Disease Control and Prevention Revised Growth reference (11). Their use provides an age- and sex-specific measure of relative adiposity and allowed for calculation of change in BMIz from baseline to 6-months and 1-year, respectively (16).

Diet was assessed via collection of two non-consecutive, weekday 24-hour diet recalls by trained registered dietitians. The initial 24-hour diet recall was collected in-person during the 3- month study visit using the University of Minnesota Nutrition Data System for Research (NDSR) software (Version 2011, Nutrition Coordinating Center, Minneapolis, MN). The NDSR software employs a multiple-pass method and a standardized portion-size manual to minimize measurement error. At this visit, participants were taught how to use the portion size manual to estimate portion sizes. The second recall was collected over the phone 3 to 21 days after the first recall using the same methodology. For 25 participants (16%), the second recall was collected in-person given difficulty in reaching them by phone within a 21-day window. Dietary data were collected for Monday through Friday only to avoid any additional variation introduced by differences in eating patterns between weekday and weekend day recalls (17). Research suggests that children in this age group, which ranged in age from 9-15 years, are capable of providing reliable 24-hour diet recalls without the assistance of a parent or guardian (18, 19).

Specific Aims and Hypotheses

The primary objective of this research is to examine the relationships of eating frequency with relative weight, total energy intake, and diet quality to better understand the role of meal and snack patterns in childhood obesity. We explore these relationships using cross-sectional data from the nationally representative NHANES, 2005-2010, and we examine both cross-sectional and prospective relationships using data from the Daily

D diet sub-study. Finally, using daily television (TV) viewing data for NHANES participants, ages 6-11 years, we elucidate the relationship between daily TV viewing and eating frequency, total caloric intake, and diet quality.

Specific Aim 1: *Determine the cross-sectional relationship of eating frequency with weight status, total energy intake, and diet quality as well as how each relationship may differ by pediatric life stage, SES, and race/ethnicity using data from NHANES 2005-2010.* The working hypothesis for this aim is that eating frequency will be positively associated with weight status and total energy intake and inversely associated with diet quality. We also hypothesize that each relationship will be stronger in adolescents, those of low SES, and racial/ethnic minorities as compared to young children, those of high SES, and non-Hispanic whites.

Specific Aim 2.1: *Evaluate the prospective relationship of eating frequency with change in BMI z-score at 6-months and 1-year and determine whether each relationship differs in elementary school-age participants versus adolescent using data from the Daily D diet sub-study.* The working hypothesis for this aim is that eating frequency will be positively related to change in BMI z-score at both 6 months and 1 year.

Specific Aim 2.2: *Examine the cross-sectional relationships of eating frequency with baseline BMI z-score, total energy intake and diet quality and determine whether each relationship differs in elementary school-age participants versus adolescents.* The working hypothesis for this aim is that eating frequency will be positively associated with baseline BMI z-score and total energy intake inversely associated with diet quality.

Specific Aim 3: *Using data cross-sectional data NHANES 2005-2010, determine how daily TV viewing is related to eating frequency, total energy intake and diet quality.* The working hypothesis for this aim is that there will be a positive association between daily TV viewing with eating frequency and total energy intake and a negative association between daily TV viewing and diet quality.

Significance of the Research

This research seeks to elucidate the relationship between eating frequency and childhood overweight and obesity, in children ages 2-18 years. Given the high prevalence of childhood obesity in the U.S. along with findings that total energy intake has increased, that diets are largely made up of low-nutrient, energy-dense foods, and that snacks largely contribute to consumption of empty calories, one would expect that the observed increase in eating frequency contributes to excess weight gain. Results from cross-sectional analyses, however, generally suggest an inverse relationship between eating frequency and weight status, while those from prospective studies are mixed. Given the equivocal nature of the literature along with a limited number of prospective studies, the Academy of Nutrition and Dietetics, the AAP, and the USDA make no specific recommendations regarding eating frequency as it relates to childhood obesity (20-22).

This analysis has the potential to clarify the literature. A cross-sectional analysis will be done in a nationally representative dataset and both cross-sectional and prospective analyses will be done in the same low-income, racially/ethnically diverse sample of school children, a population at high risk for poor diet and its health-related consequences. Application of a definition for an eating occasion that is consistent with previous studies and use of a single dietary assessment method will aid in interpretation of findings. Finally, if results suggest that eating an increased number eating occasions protects against or contributes to overweight and obesity, this analysis may inform interventions designed to reduce childhood obesity incidence.

References

1. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of Obesity and Trends in Body Mass Index Among US Children and Adolescents, 1999-2010. *J Am Med Assoc*. 2012;**307**(5):483-490.

2. Reedy J, Krebs-Smith SM. Dietary Sources of Energy, Solid Fats, and Added Sugars among Children and Adolescents in the United States. *J Am Diet Assoc*. 2010;**110**(10):1477-1484.

3. Anderson S, Economos C, Must A. Active play and screen time in US children aged 4 to 11 years in relation to sociodemographic and weight status characteristics: a nationally representative cross-sectional analysis. *BMC Public Health*. 2008;**8**:366.

4. Rideout V, Foehr U, Roberts D. Generation M2: Media in the lives of 8- to 18-year olds. Menlo Park, CA: Kaiser Family Foundation, 2010.

5. Barlow SE. Expert committee recommendations regarding the prevention, assessment and treatment of child and adolescent overweight and obesity: summary report. *Pediatrics*. 2007;**120**:S164-S192.

6. Piernas C, Popkin BM. Trends in snacking among U.S. children. *Health Aff*. 2010;**29**(3):398-404.

7. Piernas C, Popkin BM. Increased portion sizes from energy-dense foods affect total energy intake at eating occasions in US children and adolescents: patterns and trends by age group and sociodemographic characteristics, 1977-2006. *Am J Clin Nutr*. 2011.

8. Center for Disease Control and Prevention. National Health and Nutrition Examination Survey: History. 2011 [cited 2013 May 9]; Available from: http://www.cdc.gov/nchs/nhanes/history.htm.

9. Continuous NHANES Web Tutorial [database on the Internet]. Center for Disease Control and Prevention. 2009 [cited September 13, 2011]. Available from: http://www.cdc.gov/nchs/tutorials/Nhanes/index_continuous.htm.

10. National Center for Health Statistics. Anthropometry and physical activity monitor procedures manual. 2005 [cited 2011 September 13]; Available from: http://www.cdc.gov/nchs/data/nhanes/nhanes_05_06/BM.pdf.

11. Center for Disease Control and Prevention. Growth Charts: Z-Score Data Files. 2009 [cited 2011 September 13]; Available from: http://www.cdc.gov/growthcharts/zscore.htm

12. Kuczmarski RJ, Ogden CL, Guo SS, Grummar-Strawn LM, Mei Z. 2000 CDC Growth Charts for the United States: methods and development. *Vital Health Stat*. 2002;**246**:1-190.

13. National Center for Health Statistics. Key Concepts About NHANES Dietary Data Collection. 2010 [cited 2011 September 12]; Available from: http://www.cdc.gov/nchs/tutorials/dietary/SurveyOrientation/DietaryDataOverview/Info2.htm.

14. Moshfegh A, Rhodes D, Baer D, Murayi T, Clemens J, Rumpler W, et al. The US Department of Agriculture Automated Multiple-pass Method reduces bias in the collection of energy intakes. *Am J Clin Nutr*. 2008;**88**(2):324-332.

15. Pietrobelli A, Faith MS, Allison DB, Gallagher D, Chiumello G, Heymsfield SB. Body mass index as a measure of adiposity among children and adolescents: A validation study. *The Journal of Pediatrics*. 1998;**132**(2):204-210.

16. Must A, Anderson S. Body mass index in children and adolescents: considerations for population-based applications. *Int J Obes*. 2006;**30**(4):590-594.

17. Hart CN, Raynor HA, Osterholt KM, Jelalian E, Wing RR. Eating and activity habits of overweight children on weekdays and weekends. *International Journal of Pediatric Obesity*. 2011;**6**(5-6):467-472.

18. Lytle LA, Nichaman MZ, Obarzanek E, Glovsky E, Montgomery D, Nicklas T, et al. Validation of 24-hour recalls assisted by food records in third-grade children. *J Am Diet Assoc*. 1993;**93**(12):1431-1436.

19. Persson Osowski C, Fjellstrom C, Olsson U, Goranzon H. Agreement between child and parent reports of 10- to 12-year-old children's meal pattern and intake of snack foods. *J Hum Nutr Diet*. 2011.

20. Meal or Eating Frequency and Overweight in Children [database on the Internet]. American Dietetic Association. 2011 [cited September 7, 2011].

21. Spear BA, Barlow SE, Ervin C, Ludwig DS, Saelens BE, Schetzina KE, et al. Recommendations for Treatment of Child and Adolescent Overweight and Obesity. *Pediatrics*. 2007;**120**(Supplement 4):S254-S288.

22. USDA, US Department of Health and Human Services. Report of the Dietary Guidelines Advisory Committee of the Dietary Guidelines for Americans, 2010. 2010 [cited 2013 January 11]; Available from: http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm.

Chapter Two

Review of the Literature

Chapter Two: Review of the Literature

Childhood overweight and obesity are defined using the Center for Disease Control and Prevention (CDC) BMI-for-age and -sex growth reference (1). Children and adolescents are considered overweight if their BMI is greater than or equal to the 85th percentile, and obese if their BMI is greater than or equal to the 95th percentile (2). Using these definitions, comparing rates from the 1960's to those from NHANES 2009-2010 suggests that the prevalence of childhood obesity has more than tripled over the last three decades (3-5). Data from NHANES 2009-2010 suggest that 17% of children ages 2 to 19 are obese, and 32% are overweight or obese (6). Furthermore, African-American, Hispanic-American, and Native American children and those of low SES are disproportionately affected (6).

Childhood obesity has considerable public health implications due to both the physical and economic costs associated with excess weight. Childhood obesity is a recognized risk-factor for many adverse physical health outcomes. Specifically, obesity in children can lead to metabolic complications during the pediatric period (7). These include increased risk for high blood pressure (8), type II diabetes (9), sleep apnea (10), asthma (11), polycystic ovarian syndrome (12), and cardiovascular disease risk factors (13). Overweight and obese children are also at increased risk for social and psychological problems, which often persist into adulthood (14-16). Further, obese children are more likely to become obese adults (17). From an economic perspective, if current obesity trends continue, it is estimated that by 2030, 86% of American adults will be overweight or obese. Based on these projections, total health care costs attributable to overweight and obesity in children and adults in the United States would total $860 billion by 2030 (18). These physical and economic costs of highlight the need for research which identify contributing causes and potential points for intervention for childhood obesity.

At the most basic level, obesity arises from an imbalance between energy expended versus energy consumed. A lack of physical activity and excessive sedentary time, particularly watching television, are therefore likely contributors to excess weight gain in childhood. Nationally representative data suggest that children's physical activity levels are well below recommendations (19). Specifically, data from the 2001-2004 NHANES show that 37% of school-aged children had low levels of play, 65% had total screen time that was higher than the AAP recommended two-hour limit, and 26% of children exhibited both behaviors concurrently (19, 20). Further, obese children were more likely than non-obese children to have low levels of active play (42% vs. 36%), total screen time greater than two hours per day (71% vs. 64%) and to have both behaviors simultaneously (33% vs. 25%) (19). TV has long been recognized as a contributor to childhood obesity. In 1985, Dietz and Gortmaker first documented the association between TV viewing and obesity in a nationally representative sample of children aged 6 to 17 years (21). Since this seminal study, TV has become an established risk factor for childhood obesity, as a sedentary behavior and due to its association with poor dietary intake (22, 23).

Several dietary behaviors are associated with excess weight gain in childhood (24-34), including increased consumption of sugar-sweetened beverages (SSB) (24, 27, 33-35), increased portion sizes (30, 31), and eating more meals away from home (24, 32). A recent evaluation of 2007-2008 NHANES dietary data found that the top energy sources for American children ages 2-18 years include desserts, pizza, and soda, and nearly 40% of total energy consumed by 2- to 18- year olds were as empty calories (36). Although modifying food choices is a well-established point of intervention for childhood obesity, the role of eating frequency remains unclear.

Trend data suggest that eating frequency has increased considerably over the last three decades as both total energy intake and childhood obesity prevalence have both increased (5, 37). Specifically, the average number of daily eating occasions increased from 3.0 in the 1970's to 5.0 in 2006 (38). Despite the parallel trends, however, the relationship between eating frequency and relative weight in children is not well understood. In adults, increased eating frequency is inversely associated with BMI (39, 40). Yet, these findings have been challenged given documented under-reporting and because controlled feeding studies have failed to show that increased eating frequency affects appetite or energy intake (41, 42). In children, the literature relating to eating frequency and childhood obesity is even more difficult to make sense of. Inconsistent findings are likely due to studies that were done several decades ago, limited prospective evaluations, methodological limitations of the cross-sectional studies, inconsistencies in the definition of eating occasions and differences in dietary assessment methods used across studies.

To date, the only intervention study to examine this relationship in children was conducted in the 1960's by Fabry, *et al*. Their school-based intervention tested the differences in excess weight gain among school-age children eating three versus seven meals per day. Despite similar energy intake levels across the two meal frequency groups, children who consumed three meals per day gained more excess weight than those who consumed seven (43). These results are not readily interpreted, however, as the data were collected in the context of a different food environment, and because energy intake was similar across eating frequency groups. This is unlikely in free-living children, as research shows that children lose their ability to regulate energy intake based on prior intake as they age (44).

Since this study, only two other investigations have prospectively examined the relationship of eating frequency with weight gain in children (45, 46). In the MIT Growth and Development Study, Thompson and colleagues used prospective data from adolescent females to examine how eating frequency affected change in BMIz over six years. They found that girls eating 4.0-5.9 times per day had a smaller increase in BMIz than those eating 6.0 or more times per day (p=0.0024) (46). Considered alone, these results suggest that additional eating occasions increase risk for obesity; however, using data from adolescent girls participating in the National Heart, Lung and Blood Institute (NHLBI) Growth Study, Ritchie observed an inverse association between eating frequency and 10-year mean BMI gains (45). Together, these three studies fail to provide a clear conclusion with respect to the role of eating frequency in childhood weight gain.

Cross-sectional studies that have examined the relationship between eating frequency and relative weight in children generally find inverse associations (47-53). In a large nationally representative sample of French children aged 3-11, Lioret, *et al*. found that number of self-defined eating occasions and snacks was inversely associated with being overweight (48). Toschke and colleagues report similar cross-sectional results, as they found that the odds of overweight and obesity decreased with each additional reported daily meal in a dose-response fashion in a sample of young German children

(50). Kaisari *et al*. performed a meta-analysis of 10 cross-sectional studies and one case-control study, including more than 18,000 children and concluded that the relationship between eating frequency and relative weight is inverse (53).

It is noteworthy that other large cross-sectional samples report no statistically significant relationship between eating frequency and weight in children (54-56). Data from the 1994-1996 Continuing Food Survey of Intake in Individuals (CFSII) suggest no statistically significant relationship between number of eating occasions and BMI (57). Similarly, in a cross-sectional analysis of data from adolescents participating in the 1970 Longitudinal Birth Cohort, Crawley and Summerbell found no statistically significant relationship between frequency of eating occasions and BMI once they excluded dieters (55). Finally, in an analysis done by Huang and colleagues using data from both the 1994-1996 and 1998 CFSII, an inverse relationship was initially observed between reported eating frequency and BMI. However, when they limited their sample to only children with plausible reported energy intakes, the inverse relationship was no longer statistically significant (58). Researchers have asserted that the inverse relationship between eating frequency and relative weight reported in cross-sectional studies may be an artifact of biased dietary recall, or more specifically, under-reporting of both energy intake and eating frequency by overweight or obese children (41, 58).

When considered independent of meals, the relationship between snacking and weight status in children is also complicated. That snacking behavior among American children has increased in recent decades is well-established. Analyses of 2003-2006 NHANES data suggest that children currently consume three snacks per day, such that, on average, snacks contribute more than 27% of total daily energy intake (59). Low-nutrient, energy-dense foods such as desserts and sugar-sweetened beverages are the major source of calories from snacks (59). Further, data from the third School Nutrition Dietary Assessment Study show that 40% of children consume a snack during the school day (60). Whereas some studies have found an inverse relationship between snacking and weight status (61, 62), others have found that more frequent snacking is associated with increased odds of overweight in children (47). These inconsistent findings are likely due to lack of a consistent definition for snacking, under-reporting by overweight and obese children, as well as the fact that overall eating patterns are not always considered. This latter issue is important because children who skip meals are more likely to snack (63, 64).

Considered together, the relationship between eating frequency and childhood weight is not clear. In addition to the methodological limitations of cross-sectional studies, a lack of prospective work, absence of a consistent definition for eating occasions, and varying dietary assessment methods, it is also possible that the relationship is unclear due to effect modification by pediatric life-stage, SES and race/ethnicity. Although differences in the relationship between eating frequency and childhood overweight and obesity have not been explicitly examined by pediatric life stage, this relationship might be expected to vary with age because of the degree of family influence on diet changes markedly over the pediatric life course as does autonomy with respect to food-related decisions. Specifically, younger children have shown to have a better ability to self-regulate intake (65), while adolescents have greater autonomy over their eating habits, have greater spending power, and consume more meals outside the home (66), particularly fast food (67). Furthermore, as students move from elementary to middle to high school, consumption of the breakfast meal and of fruits, vegetables, and milk decreases and consumption of soft drinks increases (68). These observations suggest that the association of number of eating occasions with BMI and weight status may differ across the life course.

It is possible that the relationship between eating frequency and relative weight differs between racial and ethnic groups. To examine the relationship between meal frequency and BMI, Franko and colleagues used data from the NHLBI Growth and Health Study (NGHS). They found that in black and white girls aged 9-10 years, those who ate three or more meals per day had lower BMI z-scores. In examining the association between meal frequency and weight status, they found significant effect modification by race, as the main effect for meal frequency was not significant, but black females who consumed consistently ate three meals per day were 1.23 times less likely to be overweight (OR: 1.23; 95% CI: 1.05-1.50) (49). Furthermore, in the Bogalusa Heart Study, a bi-racial sample of 1562 children aged 10 years at time of data collection, researchers report that the total number of meals consumed was inversely associated with obesity in African American females (47). This relationship was non-significant in both white and African American males and, notably, the association was positive in white females. Further, in an analysis of data from several cycles of NHANES, Kant and Graubard found that although number of eating occasions increased over time in all race/ethnic groups, the increase in non-Hispanic black and Mexican Americans in pre-school-age children and in adolescents was significantly greater than in non-Hispanic whites ($p<0.02$) (69). These results suggest that the relationship between eating frequency and childhood obesity may differ by race/ethnicity.

In the relationship between eating frequency and weight in children, there also may be differences between children of high and low SES. Research suggests that children from low SES families are more likely to consume more servings of SSBs (34), whereas those from families of higher SES are more likely to snack (59). Moreover, children from low SES families are less likely to consume fruit and vegetables and eat family meals, which may put them at greater risk for consuming lower quality diets, one of the proposed mechanisms by which eating frequency may affect childhood weight status (67). Therefore, the effect of SES should be considered in the relationship between number of eating occasions and childhood obesity.

Finally, as previously discussed, TV viewing is an established risk factor for childhood obesity as a sedentary behavior that is often accompanied by poor dietary intake (22, 23). Research suggests that both children and adults passively consume excessive amounts of energy dense foods while watching TV (22). In a study of elementary school-age children with mean age 11.7 years, each additional hour of TV viewing was associated with consumption of an additional 106 kcals/day (95% CI: 61-150 kcals/day) (70). In addition to increasing total energy intake (70-72), watching TV is inversely associated with fruit and vegetable consumption (73-75) and positively associated with consumption of energy-dense snacks (76) and SSB (72) in children. One proposed mechanism by which TV viewing affects dietary intake is food advertising. An expert committee at the Institutes of Medicine concluded that food marketing to children is effective, as it influences both food preference and purchase requests (77). Another way in which TV viewing may affect dietary intake is through distracted or passive eating, which may affect eating frequency (22). This hypothesis has been less well explored; however, overweight and obese teens report ‘unconsciously’ eating foods high in sugar, salt and fat while watching TV (78). Further support for this mechanism is national trend data which suggest a parallel increase between TV viewing and eating frequency in children. Accordingly, distracted or passive eating associated with TV viewing may be responsible for the observed increase in eating frequency (38). Given these findings, it is important to examine how TV viewing may affect eating frequency in children.

References

1. Kuczmarski RJ, Ogden CL, Grummar-Strawn LM, Flegal KM. CDC growth charts: United States. *Adv Data*. 2000;**314**:1-27.

2. Barlow SE. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. *Pediatrics*. 2007;**120**:S164-S192.

3. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents. *Journal of the American Medical Association*. 2002;**288**(14):1728-1732.

4. Ogden CL, Carroll MD, Curtin LR. Prevalence of high body mass index in US children and adolescents, 2007-2008. *Journal of the American Medical Association*. 2010;**303**(3):242-249.

5. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of Obesity and Trends in Body Mass Index Among US Children and Adolescents, 1999-2010. *J Am Med Assoc*. 2012;**307**(5):483-490.

6. Ogden CL, Carroll MD, Curtin LR. Prevalence of high body mass index in US children and adolescents, 2007-2008. *J Am Med Assoc*. 2010;**303**(3):242-249.

7. Ebbeling CB, Pawlack DB, Ludwig DS. Childhood obesity: public-health crisis, common sense cure. *Lancet*. 2002;**360**:473-482.

8. Faulkner B, Gidding SS, Ramirez-Garnica G. The relationship of body mass index and blood pressure in primary care pediatric patients. *Journal of Pediatrics*. 2005;**148**:195-200.

9. Fagot-Campagna A, Pettitt DJ, Engelgau MM. Type 2 diabetes among North American children and adolescents: An epidemiologic review and a public health perspective. *Journal of Pediatrics*. 2000;**136**:664-672.

10. Wing YK, Hui SH, Pak WM. A controlled study of sleep related disordered breathing in obese children. *Archives of Disease in Childhood*. 2003;**88**:1043-1047.

11. Ford ES. The epidemiology of asthma. *Journal of Allergy and Clinical Immunology*. 2005;**115**:897-909.

12. Guttmann-Bauman I. Approach to adolescent polycystic ovary syndrome in the pediatric endocrine community in the USA. *Journal of Pediatric Endocrinology and Metabolism*. 2005;**18**:499-506.

13. Institute of Medicine (IOM). Childhood Obesity in the United States: Facts and Figures. Washington, D.C.: IOM; 2004.

14. Must A, Spadano J, Coakley EH. The disease burden associated with overweight and obesity. *Journal of the American Medical Association*. 1999;**282**(16):1523-1529.

15. Swartz M, Puhl R. Childhood obesity: a societal problem to solve. *Obes Rev*. 2003;**4**(1):57-71.

16. Dietz W. Health consequences of obesity in youth: Childhood predictors of adult disease. . *Pediatrics*. 1998;**101**:518-525.

17. Serdula MK, Ivery D, Coates RJ, Freedman DS. Do obese children become obese adults? A review of the literature. *Prev Med*. 1993;**22**:167-177.

18. Wang Y, Beydoun MA, Liang L, Caballero B, Kumanyika SK. Will All Americans Become Overweight or Obese? Estimating the Progression and Cost of the US Obesity Epidemic. *Obesity*. 2008;**16**(10):2323-2330.

19. Anderson S, Economos C, Must A. Active play and screen time in US children aged 4 to 11 years in relation to sociodemographic and weight status characteristics: a nationally representative cross-sectional analysis. *BMC Public Health*. 2008;**8**:366.

20. Barlow SE. Expert committee recommendations regarding the prevention, assessment and treatment of child and adolescent overweight and obesity: summary report. *Pediatrics*. 2007;**120**:S164-S192.

21. Dietz WH, Gortmaker SL. Do We Fatten Our Children at the Television Set? Obesity and Television Viewing in Children and Adolescents. *Pediatrics*. 1985;**75**(5):807-812.

22. Ebbling CB, Pawlak DB, Ludwig DS. Childhood obesity: public health crisis, common sense cure. *Lancet*. 2002;**360**:473-482.

23. French SA, Story M, Jeffery RW. Environmental influences on eating and physical activity *Annu Rev Public Health*. 2001;**22**(1):309-335.

24. Must A, Barish EE, Bandini LG. Modifiable risk factors in relation to changes in BMI and fatness: what have we learned from prospective studies of school-aged children[quest]. *Int J Obes*. 2009;**33**(7):705-715.

25. Ebbeling CB, Feldman HA, Osganian SK, Chomitz VR, Ellenbogen SJ, Ludwig DS. Effects of Decreasing Sugar-Sweetened Beverage Consumption on Body Weight in Adolescents: A Randomized, Controlled Pilot Study. *Pediatrics*. 2006;**117**(3):673-680.

26. Lin B-H, Morrison RM. Higher fruit consumption linked with lower body mass index. *Food Rev*. 2002;**25**:28-32.

27. Lise D, Anna F, Manon G, Kelly P. Regular Sugar-Sweetened Beverage Consumption between Meals Increases Risk of Overweight among Preschool-Aged Children. *J Am Diet Assoc*. 2007;**107**(6):924-934.

28. Ludwig DS, Peterson K, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. *Lancet*. 2001;**357**:505-508.

29. Piernas C, Popkin BM. Trends in snacking among U.S. children. *Health Affairs*. 2010;**29**(3):398-404.

30. Rolls BJ, Engell D, Birch LL. Serving portion size influences 5-year old but not 3-year old children's food intake. *J Am Diet Assoc*. 2000;**100**:232-234.

31. Sherry B. Food behaviors and other strategies to prevent and treat pediatric overweight. *Int J Obes*. 2005;**29**:S116 - S126.

32. Taveras EM, Berkey CS, Rifas-Shiman SL, Ludwig DS, Rockett HRH, Field AE. Assoication of consumption of fried food away from home with body mass index and diet quality in older children and adolescents. *Pediatrics*. 2005;**116**:e518-e524.

33. Wang YC, Bleich SN, Gortmaker SL. Increasing Caloric Contribution From Sugar-Sweetened Beverages and 100% Fruit Juices Among US Children and Adolescents, 1988-2004. *Pediatrics*. 2008;**121**(6):e1604-1614.

34. Ogden CL, Kit BK, Carroll MD, Park S. Consumption of sugar drinks in the United States, 2005-2008. Hyattsville, MD: National Center for Health Statistics, 2011.

35. Ludwig DS, Peterson KE, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. *Lancet*. 2001;**357**:505-508.

36. Reedy J, Krebs-Smith SM. Dietary Sources of Energy, Solid Fats, and Added Sugars among Children and Adolescents in the United States. *J Am Diet Assoc*. 2010;**110**(10):1477-1484.

37. Piernas C, Popkin BM. Increased portion sizes from energy-dense foods affect total energy intake at eating occasions in US children and adolescents: patterns and trends by age group and sociodemographic characteristics, 1977-2006. *Am J Clin Nutr*. 2011.

38. Popkin BM, Duffy KJ. Does hunger and satiety drive eating anymore? Increasing eating occasions and decreasing time between eating occasions in the United States. *Am J Clin Nutr*. 2010;**91**:1342-1347.

39. Kant AK, Schatzkin A, Graubard BI, Ballard-Barbash R. Frequency of eating occasions and weight change in the NHANES I Epidemiologic Follow-up Study. *Int J Obes Relat Metab Disord*. 1995;**19**:468-474.

40. Fabry P, Hejl Z, Fodor J, Braun T, Zvolankova K. The frequency of meals: its relation to overweight, hypercholesterolaemia, and decreased glucose tolerance. *Lancet*. 1964;**18**(614-615).

41. Bellisle F, McDevitt R, Prentice A. Meal frequency and energy balance. *1997*. 1997;**77**(Suppl. 1):S57-S70.

42. McCrory MA, Howarth NC, Roberts SB, Huang TT-K. Eating Frequency and Energy Regulation in Free-Living Adults Consuming Self-Selected Diets. *J Nutr*. 2011;**141**(1):148-153.

43. Fabry P, Hejda S, Cerny K, Osancova MA, Pechar J. Effect of meal frequency in schoolchildren. *Am J Clin Nutr*. 1966;**18**:358-361.

44. Marmonier C, Chapelot D, Louis-Sylvestre J. Effects of macronutrient content and energy density of snacks consumed in a satiety state on the onset of the next meal. *Appetite*. 2000;**34**:161-168.

45. Ritchie LD. Less frequent eating predicts greater BMI and waist circumference in female adolescents. *Am J Clin Nutr*. 2012;**95**(2):290-296.

46. Thompson OM, Ballew C, Resnicow K, Gillespie C, Must A, Bandini L, et al. Dietary pattern as a predictor of change in BMI z-score among girls. *Int J Pediatr Obes*. 2006;**30**:176-182.

47. Nicklas T, Yang S, Baranowksi T, Zakeri I, Berenson G. Eating patterns and obesity in children: the Bogalusa heart study. *Am J Prev Med*. 2003;**25**(1):9-16.

48. Lioret S, Touvier M, Lafay L, Volatier JL, Maire B. Are eating occasions and their energy content related to child overweight and socioeconomic status? *Obesity* 2008;**16**:2518-2523.

49. Franko DL, Striegel-Moore RH, Thompson D, Affenito SG, Schreiber GB, Daniels SR, et al. The relationship between meal frequency and body mass index in black and white adolescent gilrs: more is less. *Int J Obes*. 2008;**32**:23-29.

50. Toschke A, Kuchenhoff H, Koletzko B, von Kries R. Meal frequency and childhood obesity. *Obes Res*. 2005;**13**(11):1932-1938.

51. Zerva A, Nassis G, Krekoukia M, Psarra G, Sidossis L. Effect of eating frequency on body composition in 9-11 year old children. *Int J Sports Med*. 2007;**28**:265-270.

52. Wurbach A, Zellner K, Kromeyer-Hauschild K. Meal patterns among children and adolescents and their associations with weight status and parental characteristics. *Public Health Nutr*. 2009;**12**(8):1115-1121.

53. Kaisari P, Yannakoulia M, Panagiotakos DB. Eating Frequency and Overweight and Obesity in Children and Adolescents: A Meta-analysis. *Pediatrics*. 2013.

54. McConahy K, Smiciklas-Wright H, Birch L, Mitchell D, Picciano M. Food portions are positively related to energy intake and body weight in early childhood. *J Peds*. 2002;**140**(3):340-347.

55. Crawley H, Summerbell C. Feeding frequency and BMI among teenagers aged 16-17 years. *Int J Obes Relat Metab Disord*. 1997;**21**(2):159-161.

56. Macdiarmid J, Loe J, Craig LCA, Masson LF, Holmes B, McNeill G. Meal and snacking patterns of school-aged children in Scotland. *Eur J Clin Nutr*. 2009;**63**(11):1297-1304.

57. Siega-Riz A, Carson T, Popkin BM. Three squares or mostly snacks - what do teens really eat? *J Adol Health*. 1998;**22**:29-36.

58. Huang TT-K, Howarth NC, Lin B-H, Roberts SB, McCrory MA. Energy intake and meal portions: associations with BMI percentile in U.S. children. *Obes Res*. 2004;**12**(11):1875-1886.

59. Piernas C, Popkin BM. Trends in snacking among U.S. children. *Health Aff*. 2010;**29**(3):398-404.

60. Briefel RR, Crepinsek MK, Cabili C, Wilson A, Gleason PM. School Food Environments and Practices Affect Dietary Behaviors of US Public School Children. *J Am Diet Assoc*. 2009;**109**(2, Supplement 1):S91-S107.

61. Vader A, Walters S, Harris T, Hoelscher D. Television viewing and snacking behaviors of fourth and eighth-grade schoolchildren in Texas. *Prev Chronic Dis*. 2009;**6**:A89.

62. Keast DR, Nicklas TA, O'Neil CE. Snacking is associated with reduced risk of overweight and reduced abdominal obesity in adolescents: National Health and Nutrition Examination Survey (NHANES) 1999-2004. *Am J Clin Nutr*. 2010;**92**(2):428-435.

63. Savige G, Macfarlane A, Ball K, Worsley A, Crawford D. Snacking behaviors of adolescents and their association with skipping meals. *Int J Behav Nutr Phys Act*. 2007;**4**(36).

64. Dwyer JT, Evans M, Stone EJ, Feldman HA, Lytle L, Hoelscher D, et al. Adolescents' Eating Patterns Influence their Nutrient Intakes. *J Am Diet Assoc*. 2001;**101**(7):798-802.

65. Rolls BJ, Engell D, Birch LL. Serving portion size influences 5-y-old but not 3-y-old children's food intake. *J Am Diet Assoc*. 2000;**100**:232-234.

66. Nielsen S, Siega-Riz A, Popkin BM. Trends in food locations and sources among adolescents and young adults. *Prev Med*. 2002;**35**:107-113.

67. Story M, Neumark-Sztainer D, French S. Individual and environmental influences on adolescent eating behaviors. *J Am Diet Assoc*. 2002;**102**((Supp)):S40-S-51.

68. Lytle LA, Seifert S, Greenstein J, McGovern P. How do children's eating patterns and food choices change over time? Results from a cohort study. *Am J Health Promot*. 2000;**14**(4):222-228.

69. Kant AK, Graubard BI. 20-year trends in dietary and meal behaviors were similar in U.S. children and adolescents of different race/ethnicity. *J Nutr*. 2011;**141**:1880-1888.

70. Sonneville KR, Gortmaker SL. Total energy intake, adolescent discretionary behaviors and the energy gap. *Int J Obes*. 2008;**32**(S6):S19-S27.

71. Temple JL, Giacomelli AM, Kent KM, Roemmich JN, Epstein LH. Television watching increases motivated responding for food and energy intake in children. *Am J Clin Nutr*. 2007;**85**(2):355-361.

72. Miller SA, Taveras EM, Rifas-Shiman SL, Gillman MW. Association between television viewing and poor diet quality in young children. *Int J Pediatr Obes*. 2008;**3**(3):168-176.

73. Harris JL, Bargh JA, Brownell KD. Priming effects of television food advertising on eating behavior. *Health Psychol*. 2009;**28**(4):404-413.

74. Coon J, Goldberg J, Rogers B, Tucker K. Relationships between use of television during meals and children's food consumption patterns. *Pediatrics*. 2001;**107**:e7.

75. Pearson N, Biddle SJH. Sedentary Behavior and Dietary Intake in Children, Adolescents, and Adults: A Systematic Review. *Am J Prev Med*. 2011;**41**(2):178-188.

76. Boyland EJ, Harrold JA, Kirkham TC, Corker C, Cuddy J, Evans D, et al. Food Commercials Increase Preference for Energy-Dense Foods, Particularly in Children Who Watch More Television. *Pediatrics*. 2011;**128**(1):e93-e100.

77. Institue of Medicine. Preventing Childhood Obesity: Health in the Balance. Koplan JP, Liverman CT, Kraak VA, editors: The National Academies Press; 2005.

78. Rich M, Patashnick J, Huecker D, Ludwig D. Living with obesity: Visual narratives of overweight adolescents. *J Adolesc Health*. 2002;**30**(2):100.

Chapter Three

Research Paper 1

The associations of eating frequency with total energy intake,

weight status and diet quality in children and adolescents:

National Health and Nutrition Examination Survey, 2005-2010

The associations of eating frequency with total energy intake, weight status and diet quality in children and adolescents: National Health and Nutrition Examination Survey, 2005-2010[1,2]

E. Whitney Evans[3*], Paul F. Jacques[3,4], Gerard E. Dallal[3,4], Jennifer Sacheck[3], Aviva Must[5]

[3]Friedman School of Nutrition Science and Policy, Tufts University, Boston, MA 02111
[4]Jean Mayer USDA Human Nutrition Research Center on Aging, Tufts University, Boston, MA 02111
[5]Department of Public Health & Community Medicine, School of Medicine, Tufts University, Boston, MA 02111

RUNNING TITLE: Eating frequency, diet, and weight in children

WORD COUNT: 4,180   NUMBER OF FIGURES: 0   NUMBER OF TABLES: 4

SUPPLMENTARY MATERIAL: N/A

AUTHOR LIST FOR INDEXING: Evans, Jacques, Dallal, Sacheck, Must

[1]This research was supported, in part, through a National Research Service Award for the NIDDK T32 Research Training Program in Nutrition and Chronic Disease (E.W. Evans) and NIDDK46200 (Boston Nutrition Obesity Research Center)

[2]Author Disclosure: E.W. Evans, P.F. Jacques, G.E. Dallal, J. Sacheck, and A. Must report no conflicts of interest.

*To Whom Correspondence should be addressed to:
E. Whitney Evans, Tufts University School of Medicine, 136 Harrison Ave, Room 128, Boston, MA 02111 (P) 617-636-3852; (F): (617) 636-4017; email: whitney.evans@tufts.edu

ABBREVIATIONS USED: AMPM (Automated Multiple Pass Method), BMI (Body Mass Index), CDC (Center for Disease Control and Prevention), DGA (Dietary Guidelines for Americans), EER (Estimated Energy Requirement), HEI-2005 (Healthy Eating Index, 2005), MEC (Mobile Examination Center), NCHS (National Center for Health Statistics), NHANES (National Health and Nutrition Examination Survey), PIR (Poverty-to-Income Ratio), USDA (United States Department of Agriculture), SES (Socio-Economic Status), SoFAAS (Solid Fat, Alcohol, and Added Sugars)

ABSTRACT

The relationship between eating frequency and weight status during childhood is unclear. Given the equivocal state of the literature, the current work was undertaken to identify possible mechanisms by which daily eating frequency, operationalized as number of reported daily eating occasions, may affect weight status. Specifically, we examined the associations of eating frequency with weight status, total energy intake and diet quality, measured by the Healthy Eating Index 2005, in 9,713 subjects, ages 2-18 years, who participated in the National Health and Nutrition Examination Survey, 2005-2010. Eating frequency was determined using one in-person 24-hour diet recall. Odds of being obese were statistically significantly lower in both elementary school-age children and adolescents with each additional reported eating occasion. Total energy intake was statistically significantly and positively associated with both BMI z-score and total energy intake in all pediatric life stage groups. Each additional eating occasion was associated with a 7.0% increase in total energy intake for preschool-age children, a 7.8% increase in elementary school-age children, and a 15.0% increase in adolescents (all $p<0.0001$). Eating frequency was associated with better diet quality in elementary school-age children and adolescents. Results suggest that eating frequency is associated with greater energy intake and higher diet quality, despite the observed inverse association with BMI z-score in elementary school-age children and adolescents. Given the shortcomings of cross-sectional diet-focused obesity studies, these paradoxical findings emphasize the need for further prospective analyses to clarify the relationship between eating frequency and excess weight gain in childhood.

INTRODUCTION

Trend data show that over the past three decades, as the prevalence of childhood obesity has more than tripled (1, 2), the average number of daily eating occasions in children shifted from 3.0 to 5.0 (3) as total daily energy intake in children ages 2-18 years increased by almost 200 calories (4). Research supports a positive association between eating frequency and total energy intake in both children and adolescents (5, 6). Together, these findings suggest that childhood obesity may, in part, be due to increased total energy intake resulting from more frequent consumption of energy dense snack foods. However, despite these well-documented trends, the relationship between eating frequency and weight status in childhood and adolescence is not well established.

To date, the only intervention study to examine this relationship in children was carried out in the 1960's, in which Fabry and colleagues examined differences in excess weight gain among school-age children receiving three versus seven meals per day. They found that children who consumed three daily meals gained more relative weight as compared to those who consumed seven, despite similar energy intake levels (7). These results are not readily interpretable, given that the food environment has changed since the 1960's and because free-living individuals may not self-regulate energy consumption well (8). The only two longitudinal studies to examine the relationship of eating frequency with weight gain in children have both been done in females and yield opposing results. Thompson *et al* found that girls who reported six or more daily eating occasions exhibited a greater increase in BMI z-score than those who reported fewer (9), while Ritchie found that girls reporting six or more daily eating occasions had a statistically significantly smaller 10-year increase in BMI as compared to those eating fewer (10). Finally, two recent reviews suggest that the cross-sectional literature generally supports an inverse relationship between eating frequency and weight in children (11, 12). While these inverse associations may be artifacts of biased dietary recall in cross-sectional studies, they further complicate the state of the literature (13). Accordingly, the Academy of Nutrition and Dietetics, the American Academy of Pediatrics, and the United States Department of Agriculture (USDA) make no recommendations regarding an ideal eating frequency as it relates to excess weight gain children (14-16).

The present analysis was done not only to examine the cross-sectional relationship between eating frequency and weight status in a nationally representative sample, but also to explore the relationships of eating frequency with total reported energy intake and diet quality to uncover possible pathways by which eating frequency may be related to weight status in children and adolescents. We hypothesize that eating frequency is associated with greater odds of overweight and obesity, positively associated with total energy intake, and inversely associated with diet quality.

SUBJECTS & METHODS

Study Design and Participants

NHANES, collected by the National Center for Health Statistics (NCHS), is a continuous program of cross-sectional surveys designed to assess the health and nutritional status of adults and children in the United States. NHANES utilizes a complex, multistage, probability sampling design to generate nationally representative samples (17). Through a health interview and physical exam, this survey provides information on demographics, physiological measurements, and diet. A complete description of data-collection methods and analytic guidelines has been detailed elsewhere (17). For purposes of this analysis, data from the three most recent continuous NHANES cycles, 2005-2006, 2007-2008, and 2009-2010, were combined. The sample for these analyses included children aged 2-18 years with complete anthropometric data and a reliable, in-person 24-hour recall. The final sample included 9,876 children. A total of 1,015 participants ages 2 to 18 years were not included in this analysis because they were missing both anthropometric and dietary data (41%), missing anthropometric data only (13%), missing dietary data only (28%), or provided unreliable 24-hour recall data (18%). Per federal guidance, the Institutional Review Board of Tufts University approved this study as non-human subjects research.

Dietary Measures

Dietary measures were determined from an in-person 24-hour diet recall obtained by a trained interviewer using the USDA Automated Multiple Pass Method (AMPM) (18). Proxy respondents reported dietary intake for children five years of age and younger at the time of participation, and proxy-assisted interviews were conducted with children six to eleven years of age. Adolescents, ages 12-18 years, reported their own intake. Research suggests that using the AMPM to collect 24-hour diet recalls yields valid accounts of food intake in children (19). For all three cycles of NHANES, participants completed two 24-hour recalls; however, prior work suggests that there may be systematic bias in reporting of eating frequency in children and adolescents resulting from mode of administration used to collect the two recalls (in-person vs. by telephone). Therefore, this analysis uses data from the in-person recall only (Appendix C).

Eating Frequency: The AMPM uses probes to collect detailed information on each food and beverage consumed as well as the name and timing of each eating occasion. Eating occasion names come from a pre-defined list including, “breakfast, lunch, dinner, supper, brunch, snack, extended consumption, drink” for English speaking participants or “desayano, almuerzo, comida, merienda, cena, entra comida, botana, bocadillo, tentempie” for Spanish-speaking participants. For purposes of these analyses, an eating occasion was defined as any distinct time when a participant reported consuming at least one food or beverage item, *excluding water*. When an eating occasion was labeled as an “extended consumption,” and it was initiated at the same time as a reported meal or snack, we combined the two occasions into a single eating occasion. This was done by identifying all times at which an extended consumption was reported at the same time as a meal or snack. Eating frequency, defined as the number of eating occasions reported over the 24-hour recall period, was determined for each participant. Previous publications on eating frequency have used a definition for eating occasions in which foods and beverages consumed within 15 minutes of each other were combined into one meal or snack (3, 20). An examination of how often eating occasions occur within 15 minutes of each other in this dataset suggests a prevalence of less than one percent of the time. Therefore, our definition is consistent with previous research while also maintaining the integrity of how children, adolescents, or proxies self-report eating occasions.

Total Energy Intake: Total energy intake was determined for each participant using the Total Nutrients File for the in-person 24-hour diet recall.

HEI-2005 Score: Diet quality was measured using the HEI-2005. The HEI-2005 is a scoring system designed to assess conformance to the 2005 Dietary Guidelines for Americans (DGA) (21). The HEI-2010, which corresponds to the 2010 DGA, is now publically available (22); however, we used the HEI-2005 as it reflects adherence to federal dietary guidance that prevailed during the time of data collection for the three NHANES surveys used in this analysis. The HEI-2005 comprises 12 nutrient- and food-based component scores which reflect whether intake of food groups and nutrients meet the standards set by the 2005 DGA. Nine of the components (fruit, whole fruit, total vegetables, dark green and orange vegetables, total grains, whole grains, milk, meat and beans, and oils) represent adequacy components for which a higher score indicates higher consumption, whereas the saturated fat, sodium, and energy from solid fat, alcohol, and added sugars (SoFAAS) represent moderation components where a higher score reflects lower consumption. With the exception of energy from SoFAAS, the HEI-2005 uses a density approach (per 1,000 calories) to reflect the 2005 DGA recommendation to meet food group and nutrient needs while maintaining energy balance (21).

Total and component HEI-2005 scores were determined for each participant using the MyPyramid Equivalents Database (23), the 2003-2004 addendum (24), and SAS code made publically available by the USDA (25). Given that the standards used to assign maximum HEI-2005 scores are based on overall population needs along with the assertion that younger children need to consume more nutrient-dense diets to achieve desired intakes without exceeding energy needs, we modified the HEI-2005 standards for each pediatric life-stage group (26). Estimated energy requirements published by the Institute of Medicine were 1,436 calories for preschool-age children, 1,805 calories for elementary school-age children, 1,982 calories for adolescent females, and 2,518 calories for adolescent males (27). Thus, HEI-2005 standards were modified using MyPyramid eating patterns for 1,400, 1,800, 2,000 and 2,400 calories, respectively (21).

Anthropometric Measurements

Height and weight were measured for each eligible participant during the MEC exam. Weight was measured in kilograms and height was measured in centimeters (28). BMI (kg/m^2) was calculated for each participant using height and weight measurements, and BMI z-scores were determined using the Center for Disease Control and Prevention (CDC) z-score data files (29, 30). The instructions and SAS code for this calculation are publically available from the CDC (31). Weight status was determined using BMI percentiles for sex and age. Participants were considered normal weight if their BMI percentile for age and sex was less than the 85th percentile, overweight if their BMI percentile for age and sex was between the 85th and 95th percentiles, and obese if their BMI percentile for age and sex was greater than or equal to the 95th percentile. In our examination of weight with total energy intake, BMI z-scores were used.

Covariates

Pediatric life stage, age in months, sex, race/ethnicity, poverty-to-income ratio (PIR), and physical activity were considered covariates. Pediatric life-stage groups were defined using age at last birthday as follows: preschool: children ages two to five years old, elementary school-age: children ages six to eleven years old; adolescent: participants ages 12-18 years old. Self-identified race/ethnicity was coded by NCHS by combining information on race and Hispanic origin. Racial/ethnic categories include non-Hispanic white, non-Hispanic black, Mexican American, and other (32). PIR, a measure of SES, is calculated as a ratio of household income to the appropriate poverty threshold for the household size.

Physical activity was assessed by questionnaire across all three cycles of NHANES 2005-2010; however, different questions were used to collect information on physical activity in children ages two to eleven years old between the 2007-2008 and 2009-2010 surveys. From 2005-2008, proxy respondents were asked to report the number of times their child played or exercised hard over the last week (NHANES variable PAQ560). In 2009-2010, proxy respondents were asked the number of days during the last week that their child was physically active for at least 60 minutes (NHANES variable PAQ706). Both survey questions yield count variables with similar means. In adolescents, 12-18 years of age, physical activity was assessed by self-report of moderate and vigorous activity. In the 2005-2006 survey, only questions on leisure time activity were asked; therefore, while more detailed questions were asked as part of the physical activity questionnaire for the 2007-2008 and 2009-2010 cycles, only physical activity from recreation was considered to keep the measure consistent across cycles (33). Adolescents were categorized as 'sedentary' if their reported weekly moderate activity totaled less than 150 minutes, 'moderately active' if it totaled 150-300 minutes, and 'active' if it exceeded 300 minutes (34).

Statistical Analyses:

All descriptive and inferential statistics were obtained using Proc Survey in SAS (Version 9.2, 2008, SAS Institute, Cary, NC) to account for the complex, multistage, probability sampling methodology used by NCHS to collect the 2005-2010 NHANES cycles. Sample weights, which account for survey non-response, over-sampling, post-stratification, and sampling error for each two-year survey, were re-scaled to represent the population at the midpoint of the combined six year survey period (17). All tests were performed at the two-sided 0.05 level of significance.

The relationship between eating frequency and weight status was estimated using multinomial logistic regression in Proc SurveyLogistic to account for three weight status outcomes, normal, overweight, and obese. The associations of eating frequency and BMIz score with total energy intake and the association eating frequency with diet quality were estimated using multivariable linear regression in Proc SurveyReg. Given its distribution, total energy intake was log transformed and geometric means are reported. Per *a priori* hypotheses, we tested for the presence of effect modification by pediatric life-stage, socioeconomic status, and race/ethnicity using an interaction term in each respective model. Where effect modification by pediatric life stage was present, separate models were fit for preschool-age, elementary school-age and adolescent participants. For each respective outcome, effect estimates are reported for an age-adjusted model, controlling for age in months, and a multivariate model: controlling for age in months, sex, race/ethnicity, PIR, and physical activity. To account for the change in physical activity assessment across survey cycles, dummy variables were created for survey cycle and physical activity, and interaction terms were included in the full multivariate models for preschool-age and elementary school-age participants. Finally, where the relationship of eating frequency with diet quality was statistically significant, the relationships between eating frequency and HEI-2005 component scores were examined by eating frequency groups.

RESULTS

Statistically significant effect modification by pediatric life stage was observed for eating frequency and each respective outcome. Accordingly, **Table 1**, which presents demographic, anthropometric and dietary characteristics of the sample, is stratified by pediatric life stage group. Each age group was about 50% female and varied by racial/ethnic frequencies. Adolescent and elementary school-age participants were more likely than preschool-age participants to be overweight and obese ($p<0.001$). With respect to diet, eating frequency decreases through childhood as preschool-age children report almost six daily eating occasions while adolescents report fewer than five ($p<0.001$). Conversely, on average, daily total energy intake increases with age, with preschool-age children reporting 1451 calories, elementary school-age children reporting 1826 calories, and adolescents reporting 1958 calories. Finally, diet quality is highest in preschool age children, but does not significantly vary between elementary school-age children and adolescents. While not shown in Table 1, physical activity assessments suggest that both preschool age children (2005-2008: 6.2 $\pm$ 0.12 times/week; 2009-2010: 6.5 $\pm$ 0.10 times/week) and elementary school age children (2005-2008: 5.9 $\pm$ 0.14 times/week; 2009-2010: 6.0 $\pm$ 0.14 times/week) are close to meeting the recommendation of 60 minutes of physical activity every day of the week. The majority of adolescents, however, were sedentary (66%), 7% were moderately active, and 27% were active based on minutes of reported moderate physical activity per week (34).

Table 2 displays stratified odds ratios which represent the odds of being overweight and the odds of being obese, relative to normal-weighted children, for each additional reported daily eating occasion. In preschool-age participants, no relationship was observed between reported eating frequency and weight status. In elementary school-age participants, after adjusting for age-in-months, race/ethnicity, sex, PIR and physical activity, each additional reported eating occasion was statistically significantly associated with lower odds of obesity (OR: 0.89; 95% CI: 0.80-0.98) but not overweight. In adolescents, in a separate but similar model, each additional eating occasion was statistically significantly associated with 18% reduced odds of being overweight and a 15% reduced odds of being obese. Of note, when physical activity was added to the final model, neither covariate substantially altered effect estimates (data not shown).

Total energy intake was statistically significantly associated with odds of obesity in each pediatric life stage group. Also shown in Table 2, after controlling for age in months, sex, race/ethnicity, PIR and physical activity, each additional reported 10 calories increased the odds of being obese by 4%. In a similar model, for each additional 100 calories reported, the odds of obesity in elementary school-age participants were 3% higher. In adolescents, the relationship differed such that for each additional 100 calories reported, an adolescent had 2% lower odds of being obese.

The relationship of eating frequency with total energy intake was statistically significant across all three pediatric life stage groups (**Table 3,** top). Effect estimates were of similar magnitude for the age-adjusted and multivariate models. In preschool-age children after adjusting for sex, race, age in months, PIR and physical activity, with each additional eating occasion, total energy intake increased by 7.0% ($p<0.0001$). Extrapolating from average energy intake reported above, this represents a mean intake of 102 calories for each additional eating occasion. In elementary school age children, total energy intake increased, on average, by 7.8% with additional eating occasion (p<0.0001), which represents a mean increase in energy intake of 142 calories for each additional eating occasion. In adolescents, the data suggest that total energy intake increased, on average, by 15.0% with each additional eating occasion, representing a mean increased intake of 294 calories for each additional eating occasion (p<0.0001).

Effect estimates for the relationship of eating frequency with diet quality (HEI-2005 total scores) are also shown in Table 3 (bottom). In both elementary school-age children and adolescents eating frequency is statistically significantly and positively associated with diet quality. For each additional eating occasion, HEI-2005 total scores increased, on average, by 0.41 units in elementary school-age children (p=0.01) and by 0.68 units in adolescents (p<0.001). To better understand the observed positive relationships elementary school-age children and adolescents, we also examined the relationship between eating frequency categories and each of the twelve HEI-2005 component scores (**Table 4**). For elementary school-age children, those with four or fewer reported daily eating occasions have statistically significantly lower scores for total fruit, whole fruit, milk, and sodium and statistically significantly higher scores for meat and beans, and energy from SoFAAS than those with six or more daily eating occasions. This finding suggests that children who report six or more daily eating occasions eat higher relative amounts of fruit, milk, and a greater percent of energy from SoFAAS and consume lower relative amounts of meat and beans and sodium as compared to those who report four or fewer daily eating occasions. In adolescents, those who reported six or more daily eating occasions had statistically significantly higher scores for total and whole fruit, total grains, milk and milk products as compared to those who reported three or fewer daily eating occasions. Finally, adolescents who reported six or more daily eating occasions also consume statistically significantly less sodium and saturated fat as compared to those who reported three or fewer daily eating occasions.

DISCUSSION

Given the equivocal literature on the role of eating frequency in weight status in children, this study was undertaken to elucidate possible mechanisms by which eating frequency may affect weight status in children. In the context of the modern food environment, one characterized by highly permissive feeding styles, availability of low-nutrient, energy dense foods and increased opportunities to eat, we hypothesized that an increased eating frequency would be associated with greater odds of overweight and obesity through a positive association with total energy intake and an inverse association with diet quality. We found that over the pediatric life course, eating frequency decreases while total energy intake increases. Unexpectedly, we observed an inverse association between reported daily eating frequency and obesity in elementary school-age children and adolescents despite a positive association between reported daily eating frequency and total energy intake. We also found that eating frequency is positively associated with diet quality in elementary school-age children and adolescents.

Our findings present an apparent paradox. It is possible that the observed inverse relationship between eating frequency and weight status is a chance finding; yet, our results are consistent with most cross-sectional studies in children and adolescents (6, 11, 35). A recent meta-analysis comprising twelve studies and over 18,000 participants ages 2-19 years, suggests that those with the highest eating frequency have lower odds of overweight and obesity compared to those with lower eating frequency(11). Accordingly, it is more likely that the observed inverse association in elementary school-age children and adolescents is due to the cross-sectional study design of NHANES. In a similar analysis carried out by Huang and colleagues using nationally representative data from the 1994-1996 and 1998 Continuing Surveys of Food Intakes by Individuals, an inverse relationship was initially observed between reported eating frequency and BMI. When they limited their sample to only children with plausible reported energy intake, the inverse relationship was no longer present (35). They conclude that the inverse relationship between eating frequency and weight in children may be an artifact of biased dietary recall, or more specifically, under-reporting of both energy intake and eating frequency by children who are overweight or obese. In their work, they did not observe a positive relationship between energy intake and weight until implausible reporters were removed. In this analysis, we observed a statistically significant, positive association between total energy intake and BMI z-score in preschool-age and elementary school-age children and an inverse association in adolescents. Given that adolescents are more likely to under-report their intake, it is possible that the observed inverse association between eating frequency and weight status in adolescents is an artifact of under-reporting.

The finding that elementary school-age children and adolescents with a higher reported daily eating frequency also have better diet quality, as represented by a higher total HEI-2005 score, may provide some insight into the aforementioned contradictory associations of eating frequency with weight status and total energy intake. Analysis of HEI-2005 component scores shows that elementary school-age children and adolescents with a higher eating frequency have higher reported intakes of total fruit, whole fruit, and milk products. Similar patterns have been identified in previous studies examining snacking and diet quality in both adolescents and adults (5, 20, 36). Further, in adolescents, those with six or more daily eating occasions have lower saturated fat and sodium intakes than those with three or fewer daily eating occasions. Our findings imply that differences in diet quality may overcome the effects of total energy intake; however, there is scant evidence to support this proposition. The role of components of a healthy diet, such as fruit and milk, in weight gain during childhood is unclear (37-40). Moreover, we observed no differences with respect to other aspects of a healthy diet pattern, such as vegetable and whole grain intake.

A final explanation for the observed findings is that the interplay between eating patterns and physical activity level is responsible for our observed relationships. Specifically, children who are more physically active may consume more total energy over an increased number of daily eating occasions and weigh less. If this were true, we would expect the addition of physical activity to our multivariate model to attenuate the observed inverse relationship between eating frequency and odds of being overweight and obese. However, the addition of physical activity had little effect on the odds of being overweight or obese in either elementary school-age children or adolescents. We attribute this to the fact that it is not possible to rule out residual confounding by physical activity. The NHANES protocol measures physical activity via questionnaire, which is reported by a proxy for elementary school-age children and self-reported for adolescents, such that random misclassification is possible.

The major limitation of this analysis is the cross sectional nature of NHANES data. Specifically, no conclusions regarding the directionality or causality of the observed associations can be made. Another potential limitation of this research is the use of a single 24-hour diet recall to determine eating frequency. Intake on a single day is not necessarily representative of long-term eating frequency given that a child's eating frequency may vary from day to day (41). Although two 24-hour recalls are available in NHANES 2005-2010, there are currently no statistical methods developed to model usual eating frequency. Further, we found that children may report eating frequency differently in-person as opposed to over the telephone (unpublished data). A major strength of this study is its use of data from three consecutive cycles of NHANES. This provides a nationally representative contemporary sample of children and adolescents and adequate power to examine these relationships stratified by pediatric life stage. Another strength provided by the use of NHANES data is the detailed dietary information in the 24-hour recall collected using the USDA's validated AMPM. Specifically, the AMPM addresses snacking behavior through questions and memory aids (36, 42).

Results from this cross-sectional analysis using contemporary nationally representative data, suggest that that a higher reported daily eating frequency is related to lower odds of being obese as well as a higher overall diet quality in elementary school-age children and adolescents, despite a higher total energy intake. These counterintuitive findings may be an artifact of under-reporting, or they may reflect that greater eating frequency, as part of an overall healthy lifestyle comprised of physical activity and a high quality diet, may not contribute to weight in children. They should not be interpreted to suggest that eating more frequently results in a lower weight, given our finding that eating frequency is positively and statistically significantly related to total energy intake. Instead, these results highlight the need for prospective studies designed to elucidate factors that influence both eating frequency and how eating frequency may affect weight gain in children and adolescents.

STATEMENT OF AUTHORS' CONTRIBUTIONS TO MANUSCRIPT

The authors have no conflicts of interest to report. EWE designed the research project, analyzed and interpreted the data, and wrote the first draft of the manuscript. PJ, GED, and JS contributed to the study design, and manuscript preparation. AM contributed to the study design, data interpretation and manuscript preparation, and she provided study oversight. EWE had primary responsibility for final content. All authors have read and approved the final manuscript.

REFERENCES

1. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents. *Journal of the American Medical Association*. 2002;**288**(14):1728-1732.

2. Ogden CL, Carroll MD, Curtin LR. Prevalence of high body mass index in US children and adolescents, 2007-2008. *Journal of the American Medical Association*. 2010;**303**(3):242-249.

3. Popkin BM, Duffy KJ. Does hunger and satiety drive eating anymore? Increasing eating occasions and decreasing time between eating occasions in the United States. *Am J Clin Nutr*. 2010;**91**:1342-1347.

4. Piernas C, Popkin BM. Food portion patterns and trends among U.S. children and the relationship to total eating occasion size 1977-2006. *J Nutr*. 2011;**141**:1159-1164.

5. Sebastian R, Goldman J, Wilkinson Enns C. Snacking patterns of U.S. adolescents: What We Eat In America, NHANES 2005-2006. Food Surveys Research Group Dietary Data Brief [Internet]. 2010 06/20/2012; (Brief No.2). Available from: http://ars.usda.gov/Services/docs.htm?docid=19476.

6. Zerva A, Nassis G, Krekoukia M, Psarra G, Sidossis L. Effect of eating frequency on body composition in 9-11 year old children. *Int J Sports Med*. 2007;**28**:265-270.

7. Fabry P, Hejda S, Cerny K, Osancova MA, Pechar J. Effect of meal frequency in schoolchildren. *Am J Clin Nutr*. 1966;**18**:358-361.

8. Marmonier C, Chapelot D, Louis-Sylvestre J. Effects of macronutrient content and energy density of snacks consumed in a satiety state on the onset of the next meal. *Appetite*. 2000;**34**:161-168.

9. Thompson OM, Ballew C, Resnicow K, Gillespie C, Must A, Bandini L, et al. Dietary pattern as a predictor of change in BMI z-score among girls. *Int J Pediatr Obes*. 2006;**30**:176-182.

10. Ritchie LD. Less frequent eating predicts greater BMI and waist circumference in female adolescents. *Am J Clin Nutr*. 2012;**95**(2):290-296.

11. Kaisari P, Yannakoulia M, Panagiotakos DB. Eating Frequency and Overweight and Obesity in Children and Adolescents: A Meta-analysis. *Pediatrics*. 2013.

12. Larson N, Story M. A review of snacking patterns among children and adolescents: what are the implications of snacking for weight status? *Childhood Obesity*. 2013;**9**(2):104-115.

13. McCrory MA, Campbell WW. Effects of eating frequency, snacking, and breakfast skipping on energy regulation: symposium overview. *J Nutr*. 2011;**141**:144-147.

14. Meal or Eating Frequency and Overweight in Children [database on the Internet]. American Dietetic Association. 2011 [cited September 7, 2011].

15. Spear BA, Barlow SE, Ervin C, Ludwig DS, Saelens BE, Schetzina KE, et al. Recommendations for Treatment of Child and Adolescent Overweight and Obesity. *Pediatrics*. 2007;**120**(Supplement 4):S254-S288.

16. U.S. Department of Agriculture, U.S. Department of Health and Human Services. Report of the Dietary Guidelines Advisory Committee of the Dietary Guidelines for Americans, 2010. 2010 [cited 2013 January 11]; Available from: http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm.

17. Continuous NHANES Web Tutorial [database on the Internet]. Center for Disease Control and Prevention. 2009 [cited September 13, 2011]. Available from: http://www.cdc.gov/nchs/tutorials/Nhanes/index_continuous.htm.

18. National Center for Health Statistics. Key Concepts About NHANES Dietary Data Collection. 2010 [cited 2011 September 12]; Available from: http://www.cdc.gov/nchs/tutorials/dietary/SurveyOrientation/DietaryDataOverview/Info2.htm.

19. Johnson RK, Driscoll P, Goran MI. Comparison of Multiple-Pass 24-Hour Recall Estimates of Energy Intake With Total Energy Expenditure Determined By the Doubly Labeled Water Method in Young Children. *Journal of the American Dietetic Association*. 1996;**96**(11):1140-1144.

20. Zizza C, XU B. Snacking is associated with overall diet quality among adults. *J Acad Nutr Diet*. 2012;**112**:291-296.

21. Guenther P, Reedy J, Krebs-Smith S. Development of the Healthy Eating Index-2005. *J Am Diet Assoc*. 2008;**108**(11):1896-1901.

22. Guenther PM, Casavale KO, Reedy J, Kirkpatrick SI, Hiza HAB, Kuczynski KJ, et al. Update of the Healthy Eating Index: HEI-2010. *Journal of the Academy of Nutrition and Dietetics*. 2013;**113**(4):569-580.

23. MyPyramid Equivalents Database, 2.0 for USDA Survey Foods, 2003-2004 [database on the Internet]. Beltsville Human Nutrition Research Center, Agricultural Research Service, USDA. 2003-2004 [cited September 11, 2012]. Available from: http://www.ars.usda.gov/services/docs.htm?docid=17558.

24. Koegel K, Kuczynski K. Addendum to the MyPyramid Equivalents Database 2.0. Alexandria, VA: USDA Center for Nutrition Policy and Promotion, Nutrition Guidance and Analysis Division,; 2011 [cited 2012 November 11]; Available from: http://www.cnpp.usda.gov/OtherProjects.htm.

25. United States Department of Agriculture. Healthy Eating Index-2005 Development and Evaluation Technical Report Support Files. 2010 [cited 2011 September 13]; Available from: http://www.cnpp.usda.gov/HealthyEatingIndex-2005report.htm.

26. Fox MK, Clark MA, Condon E, Wilson A. Diet quality of school-age children in the U.S. and association with participation in the school meal programs. Cambridge, MA: Mathematica Policy Research, Inc, 2010 Contract No.: 6436-005.

27. Institue of Medicine. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington, DC: National Academies Press; 2005. Available from: http://www.nal.usda.gov/fnic/DRI/DRI_Energy/energy_full_report.pdf.

28. National Center for Health Statistics. Anthropometry and physical activity monitor procedures manual.. 2005 [cited 2011 September 13]; Available from: http://www.cdc.gov/nchs/data/nhanes/nhanes_05_06/BM.pdf.

29. Center for Disease Control and Prevention. Growth Charts: Z-Score Data Files. 2009 [cited 2011 September 13]. Available from: http://www.cdc.gov/growthcharts/zscore.htm

30. Kuczmarski RJ, Ogden CL, Guo SS, Grummar-Strawn LM, Mei Z. 2000 CDC growth charts for the United States: Methods and development. *Vital Health Stat*. 2002;**246**:1-190.

31. Center for Disease Control and Prevention. A SAS Program for the CDC Growth Charts. 2011.

32. National Center for Health Statistics. Analytic Note Regarding 2007-2010 Survey Design Changes and Combining Data Across other Survey Cycles 2011 [cited 2011 Septmeber 13]; Available from: http://www.cdc.gov/nchs/data/nhanes/analyticnote_2007-2010.pdf.

33. National Center for Health Statistics. 2009 - 2010 Data Documentation, Codebook, and Frequencies: Physical Activity. 2011 [cited 2012 December 13]; Available from: http://www.cdc.gov/nchs/nhanes/nhanes2009-2010/PAQ_F.htm.

34. U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans: Appendix 1 – Translating scientific evidence about total amount and intensity of physical activity into guidelines. 2008 [cited 2012 June 15]; Available from: http://www.health.gov/paguidelines/guidelines/appendix1.aspx.

35. Huang TT-K, Howarth NC, Lin B-H, Roberts SB, McCrory MA. Energy intake and meal portions: associations with BMI percentile in U.S. children. *Obes Res*. 2004;**12**(11):1875-1886.

36. Sebastian R, Cleveland L, Goldman J. Effect of snacking frequency on adolescents' dietary intakes and meeting national recommendations. *J Adol Health*. 2008;**42**:503-511.

37. Must A, Barish E, Bandini L. Modifiable risk factors in relation to changes in BMI and fatness: what we have learned from prospective studies of school-aged children. *Int J Obes*. 2009;**33**:705-715.

38. Berkey C, Rockett H, Willett W, Colditz G. Milk, dairy fat, dietary calcium, and weight gain. *Arch Pediatr Adolesc Med*. 2005;**159**:543-550.

39. Field A, Gillman M, Rosner B, Rockett H, Colditz G. Association between fruit and vegetable intake and change in body mass index among a large sample of children and adolescents in the United States. *Int J Obes Relat Metab Disord*. 2003;**27**:821-826.

40. Must A, Phillips S, Bandini L. Longitudinal fruit and vegetable consumption, fiber and glycemic load as predictors of fatness and relative weight change over adolescence in girls. *Obes Res*. 2005;**13**:A152-A153.

41. Willett W. Nutritional Epidemiology. Second ed. New York: Oxford University Press; 1998.

42. Raper N, Perloff B, Ingwersen I, Steinfeldt L, Anand J. An overview of USDA's dietary intake data system. *J Food Comp Anal*. 2004;**17**:545–555.

Table 1. Demographic and dietary characteristics for children and adolescents, ages 2-18 years, who participated in the National Health and Nutrition Examination Survey, 2005-2010[1]

Variable	Preschool	Elementary School	Adolescents	p-value[2]
Number of subjects (n=)	2,603	3,287	3,986	--
		Demographics		
Age, years (mean, (SE))	3.47 (0.04)	8.48 (0.04)	15.0 (0.06)	p<0.001
Sex (% female)	48.0%	49.5%	49.0%	p=0.30
Race-Ethnicity				p<0.001
Non-Hispanic White	854	983	1190	
Non-Hispanic Black	558	828	1137	
Mexican-American	777	962	1132	
Other	414	514	527	
Poverty-to-Income Ratio (PIR)				p=0.02
PIR < 1.30	1407	1527	1763	
1.30 < PIR < 3.50	786	1107	1362	
PIR $\geq$ 3.50	410	653	861	
		Anthropometrics		
Weight Status[3] (%)				p<0.001
Normal weight	75.8%	64.2%	61.7%	
Overweight	12.4%	15.5%	16.4%	
Obese	11.8%	20.3%	21.9%	
Diet	<- - - - -	*Mean (SE)*	- - - - ->	
Daily Eating Frequency	5.94 (0.05)	5.25 (0.04)	4.70 (0.04)	p<0.001
Total energy intake (kcal/day)[4]	1451.0 (1.0)	1826.2 (1.0)	1958 (1.0)	p<0.001
Diet Quality (HEI-2005 score)	48.3 (0.38)	45.6 (0.34)	45.4 (0.36)	p<0.001

[1]Children ages 2 to 18 years with one reliable 24 hour diet recall and complete BMI data
[2]Determined using Proc SurveyFreq and the Rao-Scott F adjusted chi-square statistic
[3]Weight status categories Normal: BMI $\geq$5th percentile and <85th percentile for sex and age; Overweight: BMI $\geq$85th percentile for sex and age, Obese: $\geq$95th percentile for sex and age
[4]Geometric mean reported; total energy intake was log-transformed to normalize distribution

Table 2. The odds of being overweight or obese based on reported daily eating frequency and energy intake in preschool-age children, elementary school-age children and adolescents participating in the National Health and Nutrition Examination Survey, 2005-2010

Eating Frequency	**Age-Adjusted Model**[1]			**Full Model**[2]		
	Odds Ratio (95% CI)[3]			***Odds Ratio (95% CI)***[3]		
	Normal	***Overweight***	***Obese***	***Normal***	***Overweight***	***Obese***
Preschool	*Ref*	0.95 (0.86-1.05)	0.96 (0.86-1.08)	*Ref*	0.98 (0.88-1.09)	0.98 (0.87-1.10)
Elementary	*Ref*	0.92 (0.81-1.04)	0.89 (0.79-0.99)	*Ref*	0.92 (0.81-1.04)	0.89 (0.80-0.98)
Adolescents	*Ref*	0.81 (0.73-0.89)	0.83 (0.76-0.90)	*Ref*	0.82 (0.73-0.91)	0.85 (0.77-0.94)
Energy Intake (per 100 calories)[4]	**Age-Adjusted Model**[1]			**Full Model**[2]		
	Odds Ratio (95% CI)[3]			***Odds Ratio (95% CI)***[3]		
	Normal	***Overweight***	***Obese***	***Normal***	***Overweight***	***Obese***
Preschool	*Ref*	1.03 (1.00-1.07)	1.03 (0.99-1.07)	*Ref*	1.02 (0.98-1.07)	1.04 (1.01- 1.08)
Elementary	*Ref*	1.01 (0.98-1.04)	1.02 (1.00-1.03)	*Ref*	1.02 (0.99-1.05)	1.03 (1.01-1.06)
Adolescents	*Ref*	0.97 (0.96-0.98)	0.98 (0.97-0.99)	*Ref*	0.96 (0.95-0.97)	0.98 (0.97- 0.99)

[1]Multinomial logistic regression models stratified by pediatric life stage and adjusted for age-in-months

[2]Multinomial logistic regression models stratified by pediatric life stage and adjusted for age-in-months, race/ethnicity, sex, poverty-to-income ratio and physical activity

[3]Odds ratios represent odds of being overweight (BMI $\geq 85^{th}$ percentile for sex and age) or obese (BMI $\geq 95^{th}$ percentile for sex and age) relative to the normal weight category group (BMI < 85^{th} percentile for sex and age)

[4]Odds ratios represent odds of being overweight for each additional 100 calories reported during the in-person 24-hour diet recall

Table 3. The relationship of eating frequency with total energy intake and with diet quality, as measured by the HEI-2005, in preschool-age children, elementary school-age children and adolescents participating in the National Health and Nutrition Examination Survey, 2005-2010

TOTAL ENERGY INTAKE	**Age-Adjusted Model[1]**	**Final Model[2]**
Preschool-age		
β-estimate ±SE	0.066 ±0.006	0.068 ±0.007
p-value	p<0.0001	p<0.0001
% change in total energy intake[3]	6.8%	7.0%
Elementary School-age		
β-estimate ±SE	0.074 ±0.008	0.075 ±0.007
p-value	p<0.0001	p<0.0001
% change in total energy intake[3]	7.7%	7.8%
Adolescents		
β-estimate ±SE	0.139 ±0.008	0.140±0.008
p-value	p<0.0001	p<0.0001
% change in total energy intake[3]	14.9%	15.0%
DIET QUALITY	**Age-Adjusted Model[1]**	**Final Model[2]**
Preschool-age		
β-estimate ±SE	0.38±0.23	0.39±0.24[5]
p-value	p=0.11	p=0.12
Elementary School-age		
β-estimate ±SE	0.38±0.18	0.41±0.16[5]
p-value	p=0.04	p=0.01
Adolescents		
β-estimate ±SE	0.92±0.16	0.68±0.17
p-value	p<0.001	p<0.001

[1] Multiple linear regression models stratified by pediatric life stage controlling for age-in-months

[2] Multiple linear regression models stratified by pediatric life stage controlling for age-in-months
sex, race/ethnicity, age in months, poverty-to-income ratio and physical activity

[3] Total energy intake log-transformed. Beta-coefficients have not been back transformed. % change in total caloric intake is reported as ((e^β1) – 1) * 100%

Table 4. Mean Healthy Eating Index-2005 component scores in elementary school-age and adolescent participants in the National Health and Nutrition Examination Survey 2005-2010 (mean (SE))[1]

HEI Component	Total Fruit	Whole Fruit	Total Veg	DOL[2]	Total Grains	Whole Grains	Milk	Meats and Beans	Oils[3]	Sat Fat	Sodium	SOFAAS[4]
Max Score	5	5	5	5	5	5	10	10	10	10	10	20
Elementary School-age Children												
Group 1: 1-4 eating occasions	2.24 (0.09)	1.90 (0.09)	1.70^{a} (0.07)	0.71^{a} (0.08)	4.24^{a} (0.05)	0.73^{a} (0.07)	4.96 (0.14)	6.60 (0.11)	4.85^{a} (0.15)	5.07^{a} (0.17)	3.84 (0.13)	7.76^{a} (0.21)
Group 2: 5 eating occasions	2.61^{a} (0.09)	2.28 (0.12)	1.61^{a} (0.07)	0.73^{a} (0.06)	4.29^{a} (0.05)	0.89^{a} (0.08)	5.50^{a} (0.19	5.90^{a} (0.17)	4.75^{a} (0.18)	5.53^{a} (0.17)	4.29^{a} (0.16)	$7.65^{a,b}$ (0.24)
Group 3: 6+ eating occasions	2.80^{a} (0.10)	2.62 (0.10)	1.60^{a} (0.07)	0.60^{a} (0.07)	4.27^{a} (0.06)	0.86^{a} (0.06)	5.60^{a} (0.11	5.80^{a} (0.14)	4.71^{a} (0.13)	5.46^{a} (0.15)	4.54^{a} (0.16)	7.21^{b} (0.22)
Adolescents												
Group 1: 1-3 eating occasions	1.27 (0.10)	0.89 (0.09)	1.93^{a} (0.09)	0.67^{a} (0.09)	3.94 (0.09)	0.68^{a} (0.07)	4.79 (0.21)	7.08^{a} (0.20)	4.29^{a} (0.27)	5.16^{a} (0.22)	3.55^{a} (0.17)	8.58^{a} (0.38)
Group 2: 4 eating occasions	1.78^{a} (0.10)	1.52^{a} (0.11)	1.86^{a} (0.08)	0.70^{a} (0.07)	4.23^{a} (0.05)	0.78^{a} (0.05)	5.32^{a} (0.16	$6.78^{a,b}$ (0.15)	4.56^{a} (0.20)	$5.38^{a,b}$ (0.20)	$3.79^{a,b}$ (0.15)	8.56^{a} (0.35)
Group 3: 5 eating occasions	$2.05^{a,b}$ (0.08)	1.74^{a} (0.09)	1.97^{a} (0.09)	0.81^{a} (0.08)	4.22^{a} (0.05)	0.70^{a} (0.06)	5.54^{a} (0.20	$6.63^{a,b}$ (0.15)	4.68^{a} (0.17)	5.73^{b} (0.22)	3.98^{b} (0.17)	8.32^{a} (0.30)
Group 4: 6+ eating occasions	2.24^{b} (0.10)	2.03 (0.11)	1.78^{a} (0.09)	0.70^{a} (0.08)	4.28^{a} (0.05)	0.79^{a} (0.05)	5.68^{a} (0.21	6.40^{b} (0.16)	4.81^{a} (0.24)	$5.5^{a,b}$ (0.13)	4.18^{b} (0.20)	8.30^{a} (0.35)

[1]Means within a column and by pediatric life stage that do not share a common letter are statistically significantly different ($p<0.05$) – no adjustment has been made for multiple comparisons
[2]Dark green, Orange vegetables and Legumes. Legumes are counted as vegetables once the standard for intake of meat and beans is met
[3]Includes non-hydrogenated vegetable oils and oils in fish, nuts, and seeds
[4]Solid fats, alcohol and added sugar (SoFAAS)

Chapter Four

Research Paper 2

The role of eating frequency on relative weight

in a low-income, racially diverse sample of school-age children:

Differences between cross-sectional and prospective finding

The role of eating frequency on relative weight in a low-income, racially diverse sample of school-age children: Differences between cross-sectional and prospective findings

E. Whitney Evans[1], MS, RD, Paul F. Jacques[1,2], ScD, Gerard E. Dallal[1,2], PhD, Jennifer Sacheck[1], PhD, Aviva Must[1,3], PhD

Affiliations: [1]Tufts University, Friedman School of Nutrition Science and Policy
[2]Tufts University, Jean Mayer USDA Human Nutrition Research Center on Aging
[3]Tufts University, School of Medicine

Address correspondence to: E. Whitney Evans, Tufts University, 136 Harrison Ave, Rm 128, Boston, MA 02111, [whitney.evans@tufts.edu], 617-636-3852

Short Title: Eating frequency and weight in school children

Abbreviations: BMI – body mass index, BMIz: BMI z-score, NDSR - Nutrition Data System for Research, NHLBI - National Heart, Lunch and Blood Institute, USDA – United States Department of Agriculture

Key Words: Eating Frequency, BMI z-score, children, meal patterns

Funding Source: This study was supported by NIH R01HL106160 and NIDDK46200 (Boston Nutrition Obesity Research Center). E. Whitney Evans receives support from the NIDDK T32 Research Training Program in Nutrition and Chronic Disease.

Financial Interests: The authors have no financial relationships relevant to this article to disclose.

Conflicts of Interest: The authors have no conflicts of interest to disclose.

What's Known on This Subject: Eating frequency in children has increased, as obesity prevalence has peaked. Despite parallel trends, cross-sectional studies generally suggest an inverse relationship, while prospective studies are equivocal. There is no agreement on what role eating frequency plays in childhood weight.

What This Study Adds: Our results uniquely contributes to the equivocal literature by showing that the cross-sectional relationship of eating frequency with baseline BMIz is inverse, whereas the prospective relationship with change in BMIz at 6-months and 1-year is positive.

ABSTRACT

Objective: The role of eating frequency in childhood weight is unclear given equivocal findings across cross-sectional and prospective studies. We sought to clarify this relationship by assessing the cross-sectional relationship of eating frequency with BMI z-score (BMIz) and the prospective relationship of eating frequency with change in BMIz over 6-months and 1-year in the same sample of school-age children.

Methods: Repeat, non-consecutive 24-hour diet recalls were collected at baseline to assess eating frequency. Height and weight were measured and converted to BMIz at baseline, 6-months, and 1-year. Cross-sectional and prospective analyses were done to determine the association between eating frequency and BMI as well as change in BMIz in a diverse sample of 176 school children, ages 9-15 years.

Results: The cross-sectional association between reported daily eating frequency and BMIz was statistically significant and inverse (β=-0.23; p=0.007). At 6-months, the nature of the relationship changed. For each additional reported daily eating occasion, a participant's BMIz increased by 0.03 units from baseline to 6-months (β_1= 0.03; $p<0.001$). This relationship remained positive at 1-year; however, it was no longer statistically significant (p=0.37).

Conclusions: Results suggest that the nature of the relationship of eating frequency with BMIz differs between cross-sectional and prospective study designs. Differences are likely due to methodological deficiencies of the cross-sectional study design and may reflect under-reporting of eating frequency by overweight and obese children. While a logistical challenge, controlled trials are needed to examine eating frequency and weight status in the modern food environment.

INTRODUCTION

Childhood obesity prevalence and eating frequency have increased in parallel from the 1970's to the present. As childhood obesity prevalence tripled, eating frequency in children increased from 3.0 to 5.0 eating occasions per day (1, 2). At the most basic level, obesity results from an imbalance between energy consumed and energy expended. Given that research suggests a positive association between eating frequency and energy intake in school-age children (3-5), eating frequency represents a potential point of intervention for childhood obesity prevention. Currently, however, there is no consensus as to what role of eating frequency plays in childhood obesity. In 2010, the U.S. Department of Agriculture's (USDA) Dietary Guidelines Advisory Committee concluded that there was insufficient evidence to determine whether the eating frequency affects obesity in children (6). Therefore, parents, schools, and clinical practitioners lack guidance as to what role meal and snack patterns play in healthy weight.

Eating frequency and childhood weight status has been studied since the 1960's when Fabry and colleagues performed a school-based intervention to test the differences in weight change relative to growth among school-age children receiving three versus seven meals per day. Despite similar energy intake levels across the two meal frequency groups, children who consumed three meals per day gained more weight compared to those who consumed seven (7). Since this seminal study, prospective and cross-sectional studies have reported both similar (4, 5, 8, 9) and conflicting results (10). Specifically, of the two prospective studies to examine this relationship, one reported an inverse association between eating frequency and 10-year mean BMI gains (9), while the other found a positive association between an eating frequency and 6-year change in BMI z-score (BMIz) (10). Most of the analyses undertaken to examine this relationship in children have been cross-sectional in nature. While their results more uniformly suggest an inverse association, study authors commonly cite methodological limitations, conclude that causal inferences should not be made from their findings and call for prospective studies (4, 5, 8, 11, 12).

Given the potential for these methodological limitations in cross-sectional diet-focused obesity research, this study was undertaken to examine both the cross-sectional and prospective relationships of eating frequency with weight in the same sample of low-income school-age children from the greater Boston area. We hypothesized a positive relationship of eating frequency with baseline BMIz and with change in BMIz over 6-months and 1-year.

SUBJECTS AND METHODS

Participant Information

This study was a diet sub-study within a randomized trial, called the Daily D Study, which was designed to determine the appropriate level of vitamin D supplementation needed to prevent serum vitamin D inadequacy in school-age children. Participants in the sub-study were recruited from the 312 currently enrolled fourth through eighth grade students at five public schools in the greater Boston area. The trial, which ran from October 2011 to December 2012, included four study visits: baseline, 3-months, 6-months, and 1-year. Other than providing a vitamin D supplement to all participants, the study protocol did not involve any dietary intervention. At the 3-month study visit, 183 students enrolled in the diet sub-study from four of the five schools. We did not recruit from the fifth school due to logistical constraints. Students were ineligible for the Daily D Study if they were currently taking vitamin D or multi-vitamin supplements, were taking oral glucocorticoids, or had rickets, cystic fibrosis, kidney disease, sarcoidosis, irritable bowel syndrome, epilepsy, or HIV/AIDS. The only additional exclusion criterion for the diet sub-study was having incomplete weight and/or height measurements at baseline. Parental informed consent and child assent was obtained for both the supplementation trial and the diet sub-study. The Tufts University Institutional Review Board approved the protocols for both the Daily D study and the diet sub-study.

Dietary Assessment

Diet was assessed via collection of two non-consecutive, weekday 24-hour diet recalls by trained registered dietitians. The initial 24-hour diet recall was collected in-person during the 3 month study visit using the University of Minnesota Nutrition Data System for Research (NDSR) software (Version 2011, Nutrition Coordinating Center, Minneapolis, MN). This methodology uses a multiple-pass method and a standardized portion-size manual to decrease measurement error. At this visit, participants were taught how to use the portion size manual to estimate portion sizes. The second recall was collected over the phone 3 to 21 days after the first recall using the same methodology. For 25 participants (16%), the second recall was collected in-person given difficulty in reaching them by phone within a 21-day window. Dietary data were collected for Monday through Friday only to avoid any additional variation introduced by differences in eating patterns between weekday and weekend day recalls (13). Research suggests that this age group, which ranged in age from 9-15 years, is capable of providing reliable 24-hour diet recalls without the assistance of a parent or guardian (14, 15).

Within the NDSR protocol, participants identify the name and time of each reported eating occasion. The names are chosen from a predefined list that includes breakfast, lunch, dinner/supper, school lunch, snack and other. For this analysis, an eating occasion was defined as any distinct time when a participant reported consuming at least one food or beverage item, *excluding water*, regardless of whether the occasion was designated as a meal (breakfast, lunch, dinner/supper or school lunch) or snack. Previous studies of eating frequency have considered eating occasions to be independent if separated by a minimum of 15 minutes (2, 10). Of the 1,574 eating occasions reported by subjects in this sample, only nine occasions (0.05%) were consumed within 15 minutes of each other and were treated as one occasion. Therefore, our definition is consistent with previous research while also maintaining the integrity of how school-age children self-define eating occasions.

No statistical methods are currently available to determine usual eating frequency from repeat 24-hour diet recalls. Analyses were therefore undertaken to determine if reported eating frequencies were similar between the in-person and over-the-phone 24-hour diet recalls. Results from a paired t-test ($t= 0.51$; $p=0.61$) suggest no differences between eating frequency estimates across the two recalls. Similarly, results from simple linear regression models in which eating frequency estimates from each type of recall were used separately, show there is no difference in the magnitude, direction or statistical significance of effect estimates. Accordingly, average eating frequency was calculated for each participant across the two, non-consecutive 24-hour diet recalls. For the 12 (7%) participants who provided only one reliable 24-hour diet recall, the estimate from their single recall was used. Given this methodology, eating frequency could take on only integer or half-integer values. Finally, eating frequency categories were created to differentiate among those who are primarily 'infrequent snackers' (1.0-3.5 daily eating occasions), 'snackers' (4.0-4.5 daily eating occasions), and 'frequent snackers' (5+ daily eating occasions).

Study Outcome:

Body mass index (BMI = weight (kg) / height (m^2)), which is commonly used as a surrogate for adiposity in children (16), was calculated from height and weight measurements collected at baseline, 6-months, and 1-year. Height was measured without shoes using a portable stadiometer (Model 214, Seca Weighing and Measuring Systems, Hanover, MD) and recorded to the closest 1/8th inch. Weight was measured without shoes in light clothing on a portable balance beam scale (Healthometer, Boca Raton, FL) and recorded to the closest 1/4 pound. All measures were taken in triplicate. BMI measurements were converted to BMIz relative to the Centers for Disease Control and Prevention (CDC) Revised Growth reference (17). Their use provides an age- and sex-specific measure of relative adiposity and allows for the assessment of change in BMIz from baseline to 6-months and 1-year, respectively (18).

Covariates

Demographic data including age, sex, and race/ethnicity were collected on the vitamin D supplementation trial consent forms. At the baseline visit, parents completed an additional questionnaire which provided information on maternal education and eligibility for free or reduced-priced school meals. Physical activity was assessed via the Block Kids Physical Activity Screener (NutritionQuest, Berkley, CA), which was completed by participants at the baseline visit. The screener asks about the frequency and duration of leisure activities, school activities, chores, and part-time employment. Its analysis provides relative estimates of total minutes of daily activity as well as minutes spent in low, moderate, and vigorous daily activity. Using these estimates with guidelines in the 2008 Physical Activity Guidelines for Americans, participants were categorized as ‘sedentary’ if their reported weekly moderate activity totaled less than 150 minutes, ‘moderately active’ if it totaled 150-300 minutes, and ‘active’ if it exceeded 300 minutes (1 minute vigorous activity = 2 minutes moderate activity) (19).

Statistical Analyses

All statistical testing was done using SAS (Version 9.2, 2008, SAS Institute, Cary, NC) at the two-sided 0.05 level of significance. We used descriptive statistics to examine baseline characteristics of our sample. Separate multivariable models were estimated using Proc Genmod to estimate associations of eating frequency with baseline BMIz, change in BMIz at 6-months, and change in BMIz at 1-year. Per *a priori* hypotheses, we tested for the presence of effect modification by age category (elementary school-age (9-11 years) versus adolescents (12+ years)), by evaluating the statistical significance of an interaction term in each model. We assessed the need to control for age in years at baseline, sex, race/ethnicity, maternal education, eligibility for free and reduced-price lunch and physical activity level in models of each respective outcome measure. Variables were retained in the model if their inclusion induced a change in the point estimate greater than 10% (20). Given differences in snacking policies and the unique food environments of the four schools represented in our sample, we controlled for school in all models. Finally, the relationship between eating frequency and each outcome was examined using eating frequency categories.

RESULTS

A total of 167 participants provided at least one reliable 24-hour diet recall and had complete anthropometric measures at baseline and 6-month visit. Some loss to follow-up was anticipated between the 6-month and 1-year visits given the transition of eighth grade participants into high school; however, only 12 students were lost to follow-up (n=155 at one year). **Table 1** displays baseline participant characteristics for the analytical samples for change in BMIz at 6 months and 1 year, respectively. At baseline, the mean age of participants was 11.4 years, 42.5% were non-Hispanic white, 46% were overweight or obese (21), and approximately 65% were eligible for free or reduced-priced school meals. On average, the sample was largely sedentary, with 65% participants reporting less than 150 minutes of physical activity per week.

Data shown in **Table 2** suggest that over the course of the study, while participant average BMI increased by 0.17 kg/m^2 at 6 months and 0.25 kg/m^2 at 1 year, BMIz decreased, on average, as did the percentage of overweight and obese participants. Specifically, relative to baseline, BMI decreased by 0.03 units over 6 months and by 0.06 units over 1 year, on average. Of the 12 participants lost to follow-up, 40% were overweight or obese and 60% were normal weight at baseline. On weekdays (Monday – Friday), participants reported a mean eating frequency of 4.5 daily eating occasions. Reported average eating frequency ranged from 2.0 to 8.5 daily eating occasions.

There was no evidence of effect modification by age category in the baseline, 6-month or 1-year models. As shown in **Table 3**, after adjusting for school and age-in-years, the cross-sectional association between reported daily eating frequency, operationalized as a continuous variable, and baseline BMIz was statistically significant and inverse (β=-0.23; p=0.007). Conversely, by the 6-month visit, the nature of the relationship changed such that reported daily eating frequency was statistically significantly and positively associated with change in BMIz. Specifically, for each additional reported daily eating occasion, a participant's BMIz increased by 0.03 units, on average, from baseline to 6 months, after controlling for school, age-in-years and physical activity (β_1= 0.03; p<0.001). Over 1 year, after controlling for school, sex, age-in-years, race/ethnicity, free or reduced-price lunch, maternal education and physical activity, the prospective relationship between reported daily eating frequency and change in BMIz remained positive; but, it was no longer statistically significant (β_1 = 0.01; p = 0.37).

To examine differences in BMIz between 'infrequent snackers' (1.0-3.5 daily eating occasions), 'snackers' (4.0-4.5 daily eating occasions), and 'frequent snackers' (5+ daily eating occasions), a categorical analysis was performed (Table 3). At baseline, 'frequent snackers' had a BMIz that was 0.44 units lower than that of 'infrequent snackers' (p<0.001). At 6 months, BMIz in the 'frequent snackers' was 0.11 units higher than 'infrequent snackers' (p<0.001). BMIz in 'snackers' did not differ from that of 'non-snackers' at baseline; yet, at 6 months, 'snackers' had an average change in BMIz that was 0.06 units higher than that of 'infrequent snackers' (p<0.001). This difference remained statistically significant at 1 year.

DISCUSSION

To our knowledge, ours is the first study to report both the cross-sectional and prospective relationships between eating frequency and weight in the same sample of school-age children. We found a statistically significant, inverse relationship between reported daily eating frequency and baseline BMIz and a statistically significant, positive relationship between reported daily eating frequency and change in BMIz at 6 months. Similarly, the analysis by eating frequency categories suggested that 'frequent snackers' had a statistically significantly lower BMIz at baseline but experienced a greater increase in BMIz at 6 months compared to those considered 'non-snackers'. These results support the assertion that the inverse relationship between eating frequency and BMIz commonly reported in cross-sectional studies is likely due to methodological limitations (22, 23).

This study uniquely contributes to the equivocal body of literature examining the relationship between eating frequency and weight in children. Both the cross-sectional and prospective analyses were done in the same sample of school-age children and suggest that the nature of the relationship between eating frequency and weight depends on study design. Our cross-sectional findings are consistent with the literature which uniformly supports an inverse relationship. A recent meta-analysis of ten cross-sectional studies concluded that those with the highest reported eating frequency had 22% lower odds of being overweight or obese as compared to those with the lowest reported eating frequency (OR: 0.78; 95% CI 0.66 to 0.94) (11). Similarly, our prospective analysis is consistent with one of two prospective studies to examine this relationship. In the MIT Growth and Development Study, Thompson and colleagues found that adolescent females with six or more eating occasions experienced a greater 6 year increase in BMIz compared to those with 3.9 or fewer reported daily eating occasions (10). Our findings mirror Thompson's in that children in our 'frequent snackers' category experienced larger gains in BMIz relative to those in the 'infrequent snackers' category.

One can speculate that the opposing cross-sectional and prospective findings in this study reflect inherent differences in the two types of study designs. First, it is likely that dietary under-reporting, particularly by overweight and obese children, accounts for the inverse relationship observed in cross-sectional analyses (24, 25). After examining this relationship in a cohort of 220 free-living adolescents and adults, Summerbell suggested that under-reporting of snacks may be greater in those who are dieting or are highly restrained eaters, which would result in a spurious finding of lower feeding frequency in association with higher BMI (26). In a subsequent study in 731 adolescents from the Longitudinal Birth Cohort Study, Crawley and Summerbell found an initially significant, inverse cross-sectional relationship between eating frequency and BMI in both males and females. However, after removing dieting males and weight-conscious females from their analysis, the relationships no longer held up (27). Further, in a similar analysis in a nationally representative sample of children, when Huang and colleagues removed subjects with implausible energy intakes, the observed inverse relationship between eating frequency and BMI was no longer statistically significant (12). A second possible explanation for the differences between cross-sectional and prospective findings is reverse causation in the cross-sectional design. Specifically, overweight or obese children may skip meals or omit snacks in attempt to lose weight or prevent further weight gain, thereby giving rise to an inverse association (23).

Our study has some notable limitations with respect to the assessment of dietary intake patterns. First, we took an average across two, non-consecutive 24-hour diet recalls to measure eating frequency. Intake on two days is not necessarily representative of usual, long-term dietary intake patterns given that a child’s eating frequency may vary from day to day (28). However, given that there are currently no statistical methods developed to model usual eating frequency, an average across two recalls provides more detail on day-to-day variation than a single 24-hour recall. Further, diet was assessed only at the 3month study visit. Therefore, our approach assumes that average daily eating frequency did not change over one calendar year. This assumption is reasonable from the baseline to the 6-month visit, given that students in the study remained in the same school food environment over the school year, which provides a similar weekday meal and snack structure. It is possible, however, that for those students with an unstructured summer environment, the assumption that eating frequency measurements from the school year hold true during the summer months may be less valid; such measurement error would lead to random misclassification. This may explain why the association between eating frequency and change on BMIz at 1 year is no longer statistically significant.

Our study also has several strengths. First, the prospective study design allowed us to follow the children through a school year as well as an entire calendar year to examine weight gain patterns in the context of eating frequency. Although no conclusions regarding the directionality or causality of the observed associations can be made from our cross-sectional analysis, our prospective analyses do support such conclusions. Second, our dietary recalls were collected by trained registered dietitians using NDSR's multiple-pass method. This methodology reduces the chance of omitting eating occasions and food items. Third, our findings can be easily compared given that eating frequency was determined from a 24-hour recall using a definition consistent with several recent studies (2, 10, 29). Finally, our sample is both racially/ethnically diverse as well as low income. Given that childhood overweight and obesity affects minorities and low-income children more significantly, this is the ideal population in which to examine this relationship (1).

Preventing childhood obesity is a public health priority. Currently, there are no recommendations as to an ideal eating frequency with respect to reducing childhood obesity risk. Given that eating patterns represent a potential point of intervention, it is important to understand this relationship in order to provide guidance to parents, schools, and practitioners, alike. The findings from this study suggest the inverse relationship observed between eating frequency and weight seen in cross-sectional analyses may reflect methodological deficiencies of the study design. Our prospective analysis suggests a statistically significant, positive relationship of eating frequency with change in BMIz over 6 months. Additional prospective studies are needed to confirm these findings. Although a logistical challenge, the school-based intervention trial, similar to that conducted by Fabry, *et al* in 1966, is needed in the context of the modern food environment.

REFERENCES

1. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity and trends in body mass index among U.S. children and adolescents, 1999-2010. *J Am Med Assoc*. 2012;**307**(5):483-490.

2. Popkin BM, Duffy KJ. Does hunger and satiety drive eating anymore? Increasing eating occasions and decreasing time between eating occasions in the United States. *Am J Clin Nutr*. 2010;**91**:1342-1347.

3. Dwyer JT, Evans M, Stone EJ, Feldman HA, Lytle L, Hoelscher D, et al. Adolescents' eating patterns influence their nutrient intakes. *J Am Diet Assoc*. 2001;**101**(7):798-802.

4. Toschke A, Kuchenhoff H, Koletzko B, von Kries R. Meal frequency and childhood obesity. *Obes Res*. 2005;**13**(11):1932-1938.

5. Macdiarmid J, Loe J, Craig LCA, Masson LF, Holmes B, McNeill G. Meal and snacking patterns of school-aged children in Scotland. *Eur J Clin Nutr*. 2009;**63**(11):1297-1304.

6. US Department of Agriculture, US Department of Health and Human Services. Report of the Dietary Guidelines Advisory Committee of the Dietary Guidelines for Americans, 2010. 2010 [cited 2013 January 11]; Available from: http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm.

7. Fabry P, Hejda S, Cerny K, Osancova MA, Pechar J. Effect of meal frequency in schoolchildren. *Am J Clin Nutr*. 1966;**18**:358-361.

8. Mota J, Fidalgo F, Silva R, Ribiero JC, Santos R, Carvalho J, et al. Relationships between physical activity, obesity and meal frequency in adolescents. *Ann Hum Biol*. 2008;**31**:1-10.

9. Ritchie LD. Less frequent eating predicts greater BMI and waist circumference in female adolescents. *Am J Clin Nutr*. 2012;**95**(2):290-296.

10. Thompson OM, Ballew C, Resnicow K, Gillespie C, Must A, Bandini L, et al. Dietary pattern as a predictor of change in BMI z-score among girls. *Int J Pediatr Obes*. 2006;**30**:176-182.

11. Kaisari P, Yannakoulia M, Panagiotakos DB. Eating Frequency and overweight and obesity in children and adolescents: A meta-analysis. *Pediatrics*. 2013.

12. Huang TT-K, Howarth NC, Lin B-H, Roberts SB, McCrory MA. Energy intake and meal portions: associations with BMI percentile in U.S. children. *Obes Res*. 2004;**12**(11):1875-1886.

13. Hart CN, Raynor HA, Osterholt KM, Jelalian E, Wing RR. Eating and activity habits of overweight children on weekdays and weekends. *International Journal of Pediatric Obesity*. 2011;**6**(5-6):467-472.

14. Lytle LA, Nichaman MZ, Obarzanek E, Glovsky E, Montgomery D, Nicklas T, et al. Validation of 24-hour recalls assisted by food records in third-grade children. *J Am Diet Assoc*. 1993;**93**(12):1431-1436.

15. Persson Osowski C, Fjellstrom C, Olsson U, Goranzon H. Agreement between child and parent reports of 10- to 12-year-old children's meal pattern and intake of snack foods. *J Hum Nutr Diet*. 2011.

16. Pietrobelli A, Faith MS, Allison DB, Gallagher D, Chiumello G, Heymsfield SB. Body mass index as a measure of adiposity among children and adolescents: A validation study. *The Journal of Pediatrics*. 1998;**132**(2):204-210.

17. Center for Disease Control and Prevention. Growth charts: Z-Score data files. 2009 [cited 2011 September 13]. Available from: http://www.cdc.gov/growthcharts/zscore.htm

18. Must A, Anderson S. Body mass index in children and adolescents: considerations for population-based applications. *Int J Obes*. 2006;**30**(4):590-594.

19. U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans: Appendix 1 – Translating scientific evidence about total amount and intensity of physical activity into guidelines. 2008 [cited 2012 June 15]; Available from: http://www.health.gov/paguidelines/guidelines/appendix1.aspx.

20. Rothman K, Greenland S, Lash T. Modern Epidemiology. Third ed. Philadelphia: Lippincott Williams & Wilkins; 2008.

21. Ogden C, Flegal K. Changes in terminology for childhood overweight and obesity. Hyattsville, MD: National Center for Health Statistics,, 2010 Contract No.: 25.

22. McCrory MA, Campbell WW. Effects of eating frequency, snacking, and breakfast skipping on energy regulation: symposium overview. *J Nutr*. 2011;**141**:144-147.

23. Bellisle F, McDevitt R, Prentice A. Meal frequency and energy balance. *1997*. 1997;**77**(Suppl. 1):S57-S70.

24. Vance VA, Woodruff SJ, McCargar LJ, Husted J, Hanning RM. Self-reported dietary energy intake of normal weight, overweight and obese adolescents. *Public Health Nutrition*. 2009;**12**(02):222-227.

25. Livingstone M, Robson P, Wallace J. Issues in dietary intake assessment of children and adolescents. *Br J Nutr*. 2004;**92**(Suppl 2):S213-S222.

26. Summerbell C, Moody RC, Shanks J, Stock MJ, Geissler C. Relationship between feeding pattern and body mass index in 220 free-living people in four age groups. *Eur J Clin Nutr*. 1996;**50**(8):513-519.

27. Crawley H, Summerbell C. Feeding frequency and BMI among teenagers aged 16-17 years. *Int J Obes Relat Metab Disord*. 1997;**21**(2):159-161.

28. Willett W. Nutritional Epidemiology. Second ed. New York: Oxford University Press; 1998.

29. Kant AK, Graubard BI. 20-year trends in dietary and meal behaviors were similar in U.S. children and adolescents of different race/ethnicity. *J Nutr*. 2011;**141**:1880-1888.

TABLES

Table 1. Baseline characteristics of elementary school-age participants in the Daily D diet sub-study[1]

	Change in BMI z-score at 6-months n=167	**Change in BMI z-score at 1-year n=155**
Female (%)	53.2%	52.3%
Age (mean ± SD)	11.4 ± 1.5 years	11.4 ± 1.5 years
Race/ethnicity (%)		
White	42.5%	43.9%
Black	12.0%	11.6%
Hispanic	12.6%	11.0%
Asian	13.2%	13.5%
Other	19.7%	20.0%
Overweight/obese (%)	46.1%	45.9%
Maternal education (%)		
No college education	48.5%	51.6%
Some college, college, and/or graduate education	51.5%	48.4%
Free or reduced-price lunch (% Yes)	64.7%	63.9%
Physical activity[2]		
Active (>300 min/week)	13.2%	14.2%
Moderately active (150 - 300 min/week)	21.6%	21.9%
Sedentary (<150 min/week)	65.2%	63.9%

[1]Sample sizes vary slightly due to missing data
[2]Minutes of moderate and vigorous physical activity measured using the Block Kids Physical Activity Screener. Categories are based on the 2008 Physical Activity Guidelines for Americans (19)

Table 2. Anthropometric measurements and reported eating frequency by study visit for elementary school-age participants in the Daily D diet sub-study

Sample Size	**Baseline visit (Oct – Dec, 2011)**[1] **n=167**	**6-month visit (Apr – June, 2012)**[1] **n=167**	**1-year visit (Oct – Dec, 2012)**[2] **n=155**
		<---------- *Mean (SD)* ---------->	
Weight (kg)	50.2 (15.3)	52.1 (15.5)	53.4 (15.8)
Height (cm)	151.8 (11.3)	154.2 (11.0)	155.8 (10.5)
BMI (kg/m^2)	21.5 (5.06)	21.7 (4.9)	21.8 (5.0)
Change in BMI (kg/m^2)	--	0.17 (0.9)	0.25 (1.1)
BMI z-score[3]	0.70 (1.14)	0.67 (1.1)	0.64 (1.1)
Change in BMI z-score	--	-0.03 (0.2)	-0.06 (0.3)
% Overweight/Obese	46.1%	46.1%	39.4%
Eating Frequency[4]	4.5 (1.02)	--	--

[1]Participants with at least one reliable 24-hour recall and non-missing baseline and 8-month anthropometrics

[2]Participants with at least one reliable 24-hour recall and non-missing baseline and 1-year anthropometrics

[3]BMI z-score determined using CDC Revised Growth Reference (17)

[4]Imputed from collection of non-consecutive repeat 24-hour recalls at the 3 month study visit

Table 3. Multivariable regression effect estimates for reported daily eating frequency with baseline BMI z-score and change in BMI z-score over 6 months and 1 year for school-age participants in the Daily D diet sub-study

	Sample Size[3] n	**Baseline BMI z-score**[4] (Cross-Sectional) *β-estimate (p-value)*	**Change in BMI z-score at 6-months**[5] (Prospective) *β-estimate (p-value)*	**Change in BMI z-score at 1-year**[6] (Prospective) *β-estimate (p-value)*
Eating Frequency [1]				
Average Reported Eating Frequency	167	-0.23 (p=0.007)	0.03 (p<0.001)	0.01 (p=0.37)
Eating Frequency Categories[2]				
'*Infrequent Snackers*': 1.0 to 3.5 daily eating occasions	28	*Referent*	*Referent*	*Referent*
'*Snackers*': 4.0 to 4.5 daily eating occasions	69	0.06 (p=0.65)	0.06 (p<0.001)	0.06 (p=0.003)
'*Frequent Snackers*': 5+ daily eating occasions	53	-0.44 (p<0.001)	0.11 (p<0.001)	0.05 (p=0.13)

[1]Coefficients represent the difference in BMI z-score per each additional eating occasion
[2]Coefficients represent the adjusted mean BMI z-score difference from 'infrequent snackers' (referent group)
[3]At 1 year, 12 students were lost to follow-up: 3 'infrequent snackers'; 4 'snackers'; and 5 'frequent snackers'
[4]Multivariable regression model adjusted for school and age
[5]Multivariable regression model adjusted for school, age and reported physical activity
[6]Multivariable regression model adjusted for school, sex, age, race/ethnicity, free or reduced-price lunch, maternal education, and physical activity

Chapter Five

Research Paper 3

The effect of eating frequency on total energy intake and diet quality

in a low-income, racially diverse sample of school-age children

The effect of eating frequency on total energy intake and diet quality in a low-income, racially diverse sample of school-age children

E. Whitney Evans[1], Paul F. Jacques[1,2], Gerard E. Dallal[1,2], Jennifer Sacheck[1], Aviva Must[1,3]

[1]Tufts University, Friedman School of Nutrition Science and Policy 150 Harrison Ave Boston, MA 02111
[2]Tufts University, Jean Mayer USDA Human Nutrition Research Center on Aging 711 Washington St Boston, MA 02111
[3]Tufts University, School of Medicine 136 Harrison Ave Boston, MA 02111

Corresponding author:
E. Whitney Evans
136 Harrison Ave, Rm 128
Boston, MA 02111
(P) 617-636-3852; (F) 617-636-4017

Keywords: Childhood obesity, snacking, energy intake, diet quality

Running Title: Eating frequency and diet in school children

Funding: This study was supported by NIH R01HL106160 and NIDDK46200 (Boston Nutrition Obesity Research Center). E. Whitney Evans receives support from the NIDDK T32 Research Training Program in Nutrition and Chronic Disease.

Acknowledgements: The authors have no conflicts of interest to report. EWE developed the research questions, collected, analyzed and interpreted the data, and wrote the first draft of the manuscript. PJ, GED, and JS contributed to the study design, and manuscript preparation. AM contributed to the study design, data interpretation and manuscript preparation, and she provided study oversight. EWE had primary responsibility for final content. All authors have read and approved the final manuscript.

ABSTRACT

Introduction: Eating frequency has increased, as energy intake and obesity prevalence have peaked in children. Despite concurrent trends, how eating frequency and snacking affect dietary intake and relative weight is unclear. This study examines how eating, snack and meal frequencies affect energy intake and diet quality in children.

Methods: Two non-consecutive 24-hour diet recalls were collected from a diverse sample of 176 school children, ages 9-15 years. Eating, meal and snack frequencies, total energy intake, and diet quality scores, measured by the Healthy Eating Index, 2005 (HEI-2005), were determined for each recall. Separate multivariable mixed models were used examine cross-sectional associations and differences were examined by age-group.

Results: Overall, 82% of participants consumed three daily meals. Eating, meal, and snack frequencies were statistically significantly and positively associated with total energy intake. Each additional reported meal and snack were associated with an 18.5% and 9.4% increase in total energy intake, respectively ($p<0.001$). The relationships of eating, meal and snack frequencies with diet quality differed by age category. In elementary school-age participants (9-11 years), total eating occasions and snacks increased HEI-2005 scores. In adolescents (12-15 years), each additional meal increased HEI-2005 scores by 5.4 points ($p=0.01$), whereas each additional snack decreased HEI-2005 scores by 2.73 units ($p=0.006$).

Conclusions: Findings suggest that snacking is positively associated with total energy intake. In elementary school-age children, snacking improves diet quality, while it decreases diet quality in adolescents. Thus, further research is needed to elucidate the role of snacking in excess weight gain in adolescents.

INTRODUCTION

Since the 1970's, childhood obesity prevalence has increased in developed countries worldwide (1). Estimates suggest that up to 60% of obese adolescents become obese adults (2) and that dietary patterns established during childhood and adolescence often persist into adulthood (3). Accordingly, there has been an increased focus on diet and dietary behaviors in children and adolescents. Consumption of sugar-sweetened beverages (SSB) (4-8), increased portion sizes (9, 10), and eating more meals away from home (5, 11) have all been positively associated with excess weight gain in childhood. Further, nationally representative U.S. trend data from children ages 2- to 18-years show that average eating frequency increased from three to five daily eating occasions between 1970 and the 2000's (12) and average total daily energy intake has increased by 184 calories over the same time frame (13). These findings, among others, have led researchers to explore what roles eating frequency plays in dietary intake and weight status in childhood.

The observed increase in eating frequency is largely attributable to snacking, given that the average American child eats three snacks per day (14). Snacking contributes nearly one-third of total calories consumed, the majority of which come from desserts and sugar-sweetened beverages (14). Further, compared to breakfast, lunch and dinner meals, snacks have a significantly higher energy density (15). Despite these findings, the cross-sectional literature on the relationships of eating frequency and snacking generally suggests an inverse relationship with weight status (16, 17).

Given the inconsistencies in the literature, no consensus exists with regard to the impact of eating frequency on relative weight in children (18, 19). A 2013 review of this relationship cited inconsistent definitions for snacking occasions, methodological limitations in cross-sectional studies, and a shortage of prospective studies and concluded that the evidence base is lacking (17). In the absence of clear guidance to parents, schools, and clinicians as to an ideal eating frequency to help reduce childhood obesity risk, the objective of this study was to explore the relationships of eating frequency, meal frequency, and snack frequency with total energy intake and diet quality in effort to elucidate possible mechanisms by which eating frequency may affect excess weight gain in children. Further, given that younger children appear to have a better ability to self-regulate intake (20), and that adolescents typically have greater autonomy over their eating habits, have greater spending power, and consume more meals outside the home (21), a secondary objective was to examine whether these associations differ between elementary school-age and adolescent participants. We hypothesized that eating frequency would be positively associated with total energy intake and inversely associated with diet quality in this racially diverse low-income sample of school-age children.

METHODS

Participant Information

This study was a diet sub-study within the Daily D Study, a randomized trial designed to determine the appropriate level of vitamin D supplementation needed to prevent serum vitamin D inadequacy in school-age children. All 312 participants who enrolled in the trial attended one of five schools in three communities in the greater Boston, Massachusetts area. The trial, which ran from October 2011 to December 2012, consisted of four study visits: baseline, 3 months, 6 months, and 1 year. Other than providing a vitamin D supplement to all participants, the trial protocol did not include any dietary intervention. At the 3-month study visit, 183 participants were recruited from four of the schools into the diet sub-study. Recruitment did not occur at the fifth school due to logistical constraints. Students were ineligible for the Daily D Study if they were currently taking vitamin D, multi-vitamin supplements or oral glucocorticoids, or had rickets, cystic fibrosis, kidney disease, sarcoidosis, irritable bowel syndrome, epilepsy, or HIV/AIDS. Participation in the diet sub-study required complete weight and height measurements at baseline and willingness to complete two 24-hour diet recalls. Parental informed consent and child assent was obtained for both the Daily D Study and the diet sub-study. Both protocols were approved by the Tufts University Institutional Review Board.

Dietary Assessment

Research suggests that school-age children are capable of providing reliable 24-hour diet recalls without the assistance of a parent or guardian (22, 23). Therefore, trained registered dietitians collected repeat, non-consecutive weekday 24-hour diet recalls directly from participants. Specifically, the first 24-hour diet recall was collected in-person at the time of the 3-month study visit, and the second 24-hour diet recall was collected 3-21 days later over the telephone. Both 24-hour diet recalls were collected using the University of Minnesota Nutrition Data System for Research (NDSR) software (Versions 2011, Nutrition Coordinating Center, Minneapolis, MN). NDSR employs a multiple-pass method and a standardized portion-size manual to decrease measurement error. Participants were taught how to use the portion size manual at the time of the in-person recall, and provided a copy for use during the telephone recall. Data collection was designed so that 24-hour diet recalls were collected on Monday through Friday on days when school was in session. This was done to avoid any variation introduced by differences in eating patterns between weekday and weekend day recalls (24).

Eating Frequency

Within the NDSR protocol, participants identify the name and time of each reported eating occasion. The names for each eating occasion are chosen from a predefined list that includes: breakfast, lunch, dinner/supper, school lunch, snack and other. For this analysis, an eating occasion was defined as any distinct time when a participant reported consuming at least one food or beverage item, *excluding water*, regardless if the occasion is designated as a meal (breakfast, lunch, dinner/supper or school lunch) or snack. No participants designated an eating occasion as “other”. Therefore, to examine possible differences in energy intake by eating occasion type, meals were defined as breakfast, lunch, dinner/supper or school lunch. Snacks were defined as a separate category. Previous publications on eating frequency have considered eating occasions to be independent if they were separated by a minimum of 15 minutes (12, 25). Of the 1,574 occasions reported by this sample, only nine occasions (0.05%) were consumed within 15 minutes of each other and were combined. Thus, our definition of eating frequency is consistent with previous research and also reflects the integrity of how elementary school-age children self-define eating occasions. Eating frequency estimates were determined separately for each 24-hour recall.

Total Energy Intake

Total energy intake estimates were determined for each 24-hour diet recall using NDSR.

Diet Quality

Diet quality was measured using the Healthy Eating Index, 2005 (HEI-2005), which is a scoring system developed by the United States Department of Agriculture (USDA) Center for Nutrition Policy and Promotion (CNPP) to measure degree of compliance with the 2005 Dietary Guidelines for Americans (2005 DGA) (26). The HEI-2005 is made up of 12 nutrient- and food-based component scores. Nine of the components (fruit, whole fruit, total vegetables, dark green and orange vegetables, total grains, whole grains, milk, meat and beans, and oils) represent adequacy components, whereas the saturated fat, sodium, and energy from solid fat, alcohol, and added sugars (SoFAAS) represent moderation components.

The standards used to assign maximum HEI-2005 scores for each component are based on overall population needs. Given that children require a more nutrient-dense diet to achieve recommended intakes without exceeding energy needs, the HEI-2005 standards have been modified (27). Mean Estimated Energy Requirements (EER) published by the Institute of Medicine were used as the basis for this modification. EER are quite different for male and female adolescents, such that adolescents have been stratified for purposes of this analysis. Specifically, for children ages 9-11 years, female adolescents ages 12-18 years, and male adolescents ages 12-18 years the HEI-2005 standards were modified according to the 1,800, 2,000 and 2,400 calorie MyPyramid eating patterns, respectively (26-28). Total and component HEI-2005 scores were calculated for each 24-hour diet recall using methodology developed for use with NDSR as well as the detailed USDA CNPP technical report (29, 30).

Covariates

Demographic data collected on the vitamin D supplementation trial consent forms included age, sex, and race/ethnicity. At the baseline visit, parents completed an additional questionnaire which provided information on maternal education and eligibility for free or reduced-priced school lunch. Physical activity was assessed by participants at the baseline visit via the Block Kids Physical Activity Screener (NutritionQuest, Berkley, CA). The screener asks about the frequency and duration of leisure activities, school activities, chores, and part-time employment. Its analysis provides relative estimates of total minutes of daily activity as well as minutes spent in low, moderate, and vigorous activity daily. These estimates along with methodology provided in the 2008 Physical Activity Guidelines for Americans were used to categorize participants as 'sedentary' if their reported weekly moderate activity totaled less than 150 minutes, 'moderately active' if it totaled 150-300 minutes, and 'active' if it exceeded 300 minutes (31). Each minute of vigorous activity was deemed equivalent to 2 minutes of moderate activity.

Statistical Analyses

All statistical analyses were conducted using SAS version 9.2 (2008; SAS Institute, Inc.), at the two-sided 0.05 level of significance. This study was powered at 80% with an estimated sample size of 150 participants. Using data from the in-person 24-hour recall, participants were initially grouped into eating frequency categories and dietary characteristics were compared. A Bonferroni adjustment was made to account for multiple comparisons. To determine whether specific dietary characteristics (eating frequency, meal frequency, and snack frequency) affect total energy intake and diet quality, measured by the total HEI-2005 score, separate multivariate mixed models were estimated using Proc Mixed. Participants provided up to two 24-hour recalls, and thus, they had up to two estimates for eating frequency, meal frequency, and snack frequency as well as total energy intake and diet quality. Accordingly, a mixed model allowed us to account for having repeat measures for each dietary variable. We tested for the presence of effect modification by age group (elementary school-age (9-11 years) versus adolescents (12-15 years) by evaluating the statistical significance of an interaction term in each model. Given differences in snacking policies and the unique food environments of the four schools represented in our sample, we controlled for school in all models. Finally, we assessed the need to control for age at baseline, sex, race/ethnicity, maternal education, free or reduced price lunch eligibility and physical activity. Variables were retained in the model if their inclusion induced a change in the point estimate greater than 10% (32).

RESULTS

A total of 176 participants provided a reliable, in-person 24-hour diet recall, and 168 participants provided a reliable, second 24-hour diet recall. Twenty-five participants provided both 24-hour diet recalls in-person, given difficulty in reaching them by phone. Despite this difference in collection methodology, there were no statistically significant differences in reported eating frequency between the two recalls with ($t=0.51$; $p= 0.61$) and without ($t=0.37$; $p=0.71$) these 25 participants. Accordingly, all 176 participants who provided at least one reliable in-person recall were included in these analyses. Participants were 9 to 15 years old, with a mean age of 11.4 years, 40% were white, and

64% were sedentary (**Table 1**). Forty-six percent were overweight or obese, and 65% were eligible for free or reduced price lunch.

In total, 82% of participants reported consuming three meals per day in their in-person 24-hour diet recall. With respect to meal location, 77% of participants consumed breakfast at home, 95% of children consumed lunch at school, and 91% of participants reported consuming dinner at home (data not shown). Participants were also grouped into eating frequency categories using data from the first in-person 24-hour diet recall, and dietary intake patterns were compared (**Table 2**). Both ‘snackers’ and ‘frequent snackers’ consumed three meals per day, on average. Finally, ‘infrequent snackers’ category consumed 2.0 fewer snacks and nearly 700 fewer calories per day, on average, as compared to ‘frequent snackers’ who consumed 2.5 snacks and over 2,000 calories per day ($p<0.05$).

There was no statistically significant effect modification by age category in the association of eating frequency with total energy intake, so results are presented on the un-stratified sample **(Table 3)**. For all participants, each additional eating occasion was statistically significantly associated with an 11.6% increase in total energy intake in a multivariable mixed model adjusted for free or reduced price lunch eligibility ($p<0.0001$). In similar but separately estimated models, each additional reported daily meal was associated with an 18.5% increase in total energy intake ($p<0.0001$), and each additional reported daily snack was associated with a 9.4% increase in total energy intake ($p<0.0001$).

Table 4 shows the relationship between eating frequency and diet quality in this sample. HEI-2005 total scores ranged from 21.9 to 82.3 units out of a possible 100.

Because associations differed between elementary school-age and adolescents participants, all multivariable mixed models have been stratified by age category. In elementary school-age participants, ages 9-11 years, the relationship between eating frequency and diet quality was statistically significant and positive. After adjusting for maternal education, free or reduced-price lunch eligibility, and physical activity, each additional reported daily eating occasion was associated with a 2.6 point increase in total HEI-2005 score (p=0.003). This relationship was not statistically significant in adolescents. In similar but separate models, the relationship between meal frequency and diet quality was positive in both age groups; however, it was statistically significant only in adolescents. Specifically, for each additional reported daily meal, adolescents' total HEI-2005 scores increased by 5.4 points (p=0.01). The relationship between reported daily snacks and diet quality was statistically significant in both life stage groups; however, it was positive in elementary-school age participants and inverse in adolescents. Finally, we used the eating frequency categories to explore the relationship between eating frequency and the 12 HEI-2005 component scores in both age groups. After adjusting for multiple comparisons, no statistically significant differences were identified

DISCUSSION

In a population of children at high risk for poor diet and its attendant consequences, eating, meal, and snack frequencies were positively associated with total energy intake, whereas the relationships with diet quality differed between meals and snacks and by age category. We hypothesized that eating frequency would be inversely associated with diet quality in light of recent dietary trends in American youth (33). Unexpectedly, in elementary school-age participants, we found that overall eating frequency and snacks positively contributed to diet quality, while the relationship of meal frequency with diet quality was not statistically significant. In adolescents, however, our results suggest that snacks detract from overall diet quality. Specifically, for each additional snack consumed by adolescent participants, total HEI-2005 scores statistically significantly decreased by 2.73 points , while each additional meal statistically significantly increased total HEI-2005 scores by 5.4 points. In other words, adolescent diet quality decreased with each additional snack and increased with each additional meal.

Why results differ between elementary school-age participants and adolescents is not entirely clear; however, longitudinal trend data suggest that diet quality decreases with the transition from early to middle adolescence, as consumption of fruit and vegetables, 100% fruit juice, and milk and milk products decrease (34, 35). It is also possible that because adolescents are generally more autonomous than elementary school-age children, they may make more of their own food choices, particularly at snack time, leading to a decrease in overall diet quality with each additional snack (36). Although we did not collect information regarding family meals, the family meal setting may explain why meals are positively associated with diet quality while snacks are inversely associated with diet quality in adolescents. Family meal frequency has been shown to be positively associated with nutrient intake patterns and inversely associated with sugar-sweetened beverage and fried food intake in both children and adolescents (37).

On average, reported eating frequency and total energy estimates were similar to national estimates (12). Interestingly, however, despite research which suggests that children who skip meals are more likely to snack, 82% of participants in this sample reported consuming three meals per day (38, 39). 'Frequent snackers' had the highest daily total energy intake, and reported 2.5 or more snacks per day. These findings support the assertion that older children and adolescents may not compensate for energy intake from snacks at subsequent meals (40). Further, after adjusting for eligibility for free or reduced-priced lunch, a statistically significant and positive association was observed for eating, meal, and snack frequencies with total energy intake. This is not only is consistent with our hypotheses, but it is also supported by the literature. Dietary data from children ages 13-16 years who participated in the Child and Adolescent Trial for Cardiovascular Health, show that total energy intake increased linearly with daily eating frequency (39). Other studies have observed a similar relationship, suggesting a positive association between daily meal and snack frequency and total energy intake (41, 42).

This study has noteworthy limitations and strengths. First, our results are valid to the extent that children and adolescents can accurately define meals and snacks. We attempted to address this potential limitation by carrying out this analysis using total eating frequency as well as reported meal and snack frequencies. Second, we did not collect information on family meals or who purchased and/or prepared meals. Accordingly, we can only hypothesize that these two constructs may have influenced our findings. Third, our findings are cross-sectional in nature such that no conclusions can be made with respect to direction or causality. Finally, generalizability of our findings may be limited beyond racially and socioeconomically diverse samples of urban school children.

This investigation also has many strengths. Further, we employed registered dietitians to collect repeat, non-consecutive 24-hour recalls using NDSR's multiple-pass method in effort to reduce under-reporting, particularly as it relates to eating occasions. Finally, our analytical design, in which we used a mixed model to account for repeat dietary measures, allowed us to account for day-to-day dietary variation. The demographic characteristics of our sample should be considered a strength of this work, given that low-income minority children are at greater risk for poor diet as well as overweight and obesity (43).

CONCLUSIONS

This study provides evidence that eating frequency, meal frequency, and snack frequency are positively associated with total energy intake in a racially and ethnically diverse cohort of low-income children ages 9 to 15 years. Results suggest that eating frequency, in general, and snacking, in particular, are positively associated with diet quality in elementary school-age participants; however, in adolescents, snack frequency is inversely associated with diet quality while meal frequency is positively associated with diet quality. These findings further support the assertion that eating frequency likely plays a role in excess childhood weight gain, despite the equivocal literature. Given the lack of prospective and experimental studies in this area, further research is needed to explore the relationships of eating frequency with weight gain in school-age children.

REFERENCES

1. Lobstein R, Baur L, Uauy R. Obesity in children and young people: a crisis in public health. *Obes Rev*. 2004;**5**(Supp 1):4-104.

2. Guo SS, Wu W, Chumlea WC, Roche AF. Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. *The American Journal of Clinical Nutrition*. 2002;**76**(3):653-658.

3. Birch LL, Fisher JO. Development of Eating Behaviors Among Children and Adolescents. *Pediatrics*. 1998;**101**(Supplement 2):539-549.

4. Ludwig DS, Peterson KE, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. *Lancet*. 2001;**357**:505-508.

5. Must A, Barish EE, Bandini LG. Modifiable risk factors in relation to changes in BMI and fatness: what have we learned from prospective studies of school-aged children. *Int J Obes*. 2009;**33**(7):705-715.

6. Lise D, Anna F, Manon G, Kelly P. Regular sugar-sweetened beverage consumption between meals increases risk of overweight among preschool-aged children. *J Am Diet Assoc*. 2007;**107**(6):924-934.

7. Wang YC, Bleich SN, Gortmaker SL. Increasing caloric contribution from sugar-sweetened beverages and 100% fruit juices among US children and adolescents, 1988-2004. *Pediatrics*. 2008;**121**(6):e1604-e1614.

8. Ogden CL, Kit BK, Carroll MD, Park S. Consumption of sugar drinks in the United States, 2005-2008. Hyattsville, MD: National Center for Health Statistics, 2011.

9. Rolls BJ, Engell D, Birch LL. Serving portion size influences 5-year old but not 3-year old children's food intake. *J Am Diet Assoc*. 2000;**100**:232-234.

10. Sherry B. Food behaviors and other strategies to prevent and treat pediatric overweight. *Int J Obes*. 2005;**29**:S116 - S126.

11. Taveras EM, Berkey CS, Rifas-Shiman SL, Ludwig DS, Rockett HRH, Field AE. Association of consumption of fried food away from home with body mass index and diet quality in older children and adolescents. *Pediatrics*. 2005;**116**:e518-e524.

12. Popkin BM, Duffy KJ. Does hunger and satiety drive eating anymore? Increasing eating occasions and decreasing time between eating occasions in the United States. *Am J Clin Nutr*. 2010;**91**:1342-1347.

13. Piernas C, Popkin BM. Food portion patterns and trends among U.S. children and the relationship to total eating occasion size 1977-2006. *J Nutr*. 2011;**141**:1159-1164.

14. Piernas C, Popkin BM. Trends in snacking among U.S. children. *Health Aff*. 2010;**29**(3):398-404.

15. Cole N, Fox MK. Diet quality of American school-age children by school lunch participation status: data from the National Health and Nutrition Examination Survey, 1999-2004. Alexandria, VA: U.S. Department of Agriculture, Food and Nutrition Service, Office of Research, Nutrition and Analysis, 2008.

16. Kaisari P, Yannakoulia M, Panagiotakos DB. Eating Frequency and Overweight and Obesity in Children and Adolescents: A Meta-analysis. *Pediatrics*. 2013.

17. Larson N, Story M. A review of snacking patterns among children and adolescents: what are the implications of snacking for weight status? *Childhood Obesity*. 2013;**9**(2):104-115.

18. Meal or eating frequency and overweight in children. Academy of Nutrition and Dietetics. 2011 [cited September 7, 2011]; Avialable from: http://andevidencelibrary.com/evidence.cfm?evidence_summary_id=21&auth=1.

19. US Department of Agriculture, US Department of Health and Human Services. Report of the Dietary Guidelines Advisory Committee of the Dietary Guidelines for Americans, 2010. 2010 [cited 2013 January 11]; Available from: http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm.

20. Rolls BJ, Engell D, Birch LL. Serving portion size influences 5-y-old but not 3-y-old children's food intake. *J Am Diet Assoc*. 2000;**100**:232-234.

21. Nielsen S, Siega-Riz A, Popkin BM. Trends in food locations and sources among adolescents and young adults. *Prev Med*. 2002;**35**:107-113.

22. Lytle LA, Nichaman MZ, Obarzanek E, Glovsky E, Montgomery D, Nicklas T, et al. Validation of 24-hour recalls assisted by food records in third-grade children. *J Am Diet Assoc*. 1993;**93**(12):1431-1436.

23. Persson Osowski C, Fjellstrom C, Olsson U, Goranzon H. Agreement between child and parent reports of 10- to 12-year-old children's meal pattern and intake of snack foods. *J Hum Nutr Diet*. 2011.

24. Hart CN, Raynor HA, Osterholt KM, Jelalian E, Wing RR. Eating and activity habits of overweight children on weekdays and weekends. *International Journal of Pediatric Obesity*. 2011;**6**(5-6):467-472.

25. Thompson OM, Ballew C, Resnicow K, Gillespie C, Must A, Bandini L, et al. Dietary pattern as a predictor of change in BMI z-score among girls. *Int J Pediatr Obes*. 2006;**30**:176-182.

26. Guenther P, Reedy J, Krebs-Smith S. Development of the Healthy Eating Index-2005. *J Am Diet Assoc*. 2008;**108**(11):1896-1901.

27. Fox MK, Clark MA, Condon E, Wilson A. Diet quality of school-age children in the U.S. and association with participation in the school meal programs. Cambridge, MA: Mathematica Policy Research, Inc, 2010 Contract No.: 6436-005.

28. Institue of Medicine. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington, DC: National Academies Press; 2005. Available from: http://www.nal.usda.gov/fnic/DRI/DRI_Energy/energy_full_report.pdf.

29. United States Department of Agriculture. Healthy Eating Index-2005 Development and Evaluation Technical Report Support Files. 2010 [cited 2011 September 13]; Available from: http://www.cnpp.usda.gov/HealthyEatingIndex-2005report.htm.

30. Miller PE, Mitchell D, Harala P, Pettit J, Smiciklas-Wright H, Hartman T. Development and evaluation of a method for calculating the Healthy Eating Index-2005 using the Nutrition Data System for Research. *Public Health Nutr*. 2010.

31. U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans: Appendix 1 – Translating scientific evidence about total amount and intensity of physical activity into guidelines. 2008 [cited 2012 June 15]; Available from: http://www.health.gov/paguidelines/guidelines/appendix1.aspx.

32. Rothman K, Greenland S, Lash T. Modern Epidemiology. Third ed. Philadelphia: Lippincott Williams & Wilkins; 2008.

33. Reedy J, Krebs-Smith SM. Dietary sources of energy, solid fats, and added sugars among children and adolescents in the United States. *J Am Diet Assoc*. 2010;**110**(10):1477-1484.

34. Nelson MC, Neumark-Sztainer D, Hannan PJ, Story M. Five-year longitudinal and secular shifts in adolescent beverage intake: Findings from Project EAT (Eating Among Teens)-II. *J Am Diet Assoc*. 2009;**109**:308-312.

35. Larson N, Neumark-Sztainer D, Hannan PJ, Story M. Trends in adolescent fruit and vegetable consumption, 1999-2004. *Am J Prev Med*. 2007;**32**:147-150.

36. Neumark-Sztainer D, Story M, Perry C, Casey M. Factors influencing food choices of adolescents: findings from focus-group discussions with adolescents. *J Am Diet Assoc*. 1999;**99**:929-937.

37. Gilman M, Rifas-Shiman S, Frazier L, Rockett H, Camargo C, Field A, et al. Family dinner and diet quality among older children and adolescents. *Arch Fam Med*. 2000;**9**:235=240.

38. Savige G, Macfarlane A, Ball K, Worsley A, Crawford D. Snacking behaviors of adolescents and their association with skipping meals. *Int J Behav Nutr Phys Act*. 2007;**4**(36).

39. Dwyer JT, Evans M, Stone EJ, Feldman HA, Lytle L, Hoelscher D, et al. Adolescents' eating patterns influence their nutrient intakes. *J Am Diet Assoc*. 2001;**101**(7):798-802.

40. Marmonier C, Chapelot D, Louis-Sylvestre J. Effects of macronutrient content and energy density of snacks consumed in a satiety state on the onset of the next meal. *Appetite*. 2000;**34**:161-168.

41. Toschke A, Kuchenhoff H, Koletzko B, von Kries R. Meal frequency and childhood obesity. *Obes Res*. 2005;**13**(11):1932-1938.

42. Macdiarmid J, Loe J, Craig LCA, Masson LF, Holmes B, McNeill G. Meal and snacking patterns of school-aged children in Scotland. *Eur J Clin Nutr*. 2009;**63**(11):1297-1304.

43. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999-2010. *J Am Med Assoc*. 2012;**307**(5):483-490.

TABLES

Table 1. Characteristics of school-age children and adolescents who participated in the Daily D diet sub-study

	Analytic Sample (n=176)[1]
Sex (% Female)	50.6%
Age (mean ± SD)	11.4 ± 1.5 years
Race/Ethnicity[1] (%)	
White	40.0%
Black	12.6%
Hispanic	13.7%
Asian	13.1%
Other	20.6%
Weight Status (% Overweight/Obese)	46.0%
Maternal Education (%)	
No college education	50.0%
Some college, college, and/or graduate education	50.0%
Qualify for Free / Reduced-Price Lunch (% Yes)	63.8%
Reported Physical Activity[2] (%)	
Active (>300 minutes/week)	14.2%
Moderately Active (150 to <300 minutes/week)	21.6%
Sedentary (<150 minutes/week)	64.2%

[1]Sample sizes vary slightly due to missing data
[2]Minutes of moderate and vigorous physical activity measured using the Block Kids Physical Activity Screener. Categories are based on the 2008 Physical Activity Guidelines for Americans (31)

Table 2. Dietary characteristics of the first in-person 24-hour diet recall provided by school-age children and adolescents who participated in the Daily D diet sub-study[1]

	'Infrequent Snackers' (n=32)	**'Snackers' (n=59)**	**'Frequent Snackers' (n=85)**
Reported Eating Frequency[2,3]	1-3 occasions/day	4 occasions/day	5+ occasions/day
		Mean (SD)	
Meal Frequency[4]	2.34 (0.65)	2.97 (0.41)[a]	2.98 (0.41)[a]
Snack Frequency[5]	0.5 (0.62)	1.0 (0.41)	2.5 (0.88)
Diet Quality[6]	49.2 (10.9)[a]	56.4 (11.5)[b]	55.5 (13.0)[a,b]
Energy Intake	1322.2 (595.2)[a]	1570.5 (435.1)[a]	2016.8 (586.9)
Average Energy per meal	495.3 (230.9)[a]	463.7 (123.4)[a]	469.1 (139.8)[a]
Average Energy per snack	300.4 (219.0)[a]	212.6 (137.8)[a]	252.0 (174.6)[a]

[1]Participants were grouped into eating frequency categories using only data from the first, in-person 24-hour recall
[2]Eating frequency: number of reported daily eating occasions for reliable first in-person 24-hour recall
[3]Means in the same row that do not share a common letter are statistically significantly different: Bonferroni adjustment made for multiple comparisons
[4]Meal frequency: number of reported daily meals (breakfast, lunch, dinner/supper) for reliable first in-person 24-hour recall
[5]Snack frequency: number of reported daily snacks for reliable in-person 24-hour recall
[6]As measured by the total Healthy Eating Index, 2005 score

Table 3. Associations of daily eating, snack and meal frequencies with total energy intake in school-age children and adolescents who participated in the Daily D diet sub-study

Energy Intake	**Total**[1] *Multivariate Effect Estimate (p-value)*	**Percentage change**[2] *Multivariate Effect Estimate (p-value)*
Eating Frequency[3]	β_1=0.11 (p<0.001)	11.6% increase in total energy intake (p<0.001)
Meal Frequency[4]	β_1=.17 (p<0.001)	18.5% increase in total energy intake (p<0.001)
Snack Frequency[5]	β_1= 0.09 (p<0.001)	9.4% increase in total energy intake (p<0.001)

[1]Effect estimates from separate mixed models which account for repeat measures and are adjusted for school and free or reduced-price lunch eligibility
[2]Total energy intake log transformed. Reported beta-coefficients have not been back transformed. Percent change in total energy intake is reported as $((e^{\beta 1}) - 1) * 100\%$
[3]Eating frequency: number of reported daily eating occasions
[4]Meal frequency: number of reported daily meals (breakfast, lunch, dinner/supper)
[5]Snack frequency: number of reported daily snacks

Table 4. Associations of eating, meal and snack frequencies with diet quality, as measured by the HEI-2005 total score, and in elementary school-age children and adolescents who participated in the Daily D diet sub-study[1]

	Elementary School-age: 9-11 years (n=92)	**Adolescents: 12-15 years (n=84)**
	β-estimate (p-value)[2]	*β-estimate (p-value)*[2]
Eating Frequency	2.60 (p=0.003)	-1.4 (p=0.16)
Meal Frequency	3.84 (p=0.06)	5.4 (p=0.01)
Snack Frequency	2.31 (p=0.02)	-2.73 (p=0.006)

[1]HEI-2005 scores range from 21.9 to 82.3 (out of a possible 100)
[2]Separate mixed multivariable models accounting for repeat dietary measures and adjusting for school, maternal education, free or reduced price lunch eligibility, and physical activity
[2]Eating frequency: number of reported daily eating occasions
[3]Meal frequency: number of reported daily meals (breakfast, lunch, dinner/supper)
[4]Snack frequency: number of reported daily snacks

Chapter Six

Research Paper 4

Does television viewing relate to weight status and

dietary intake patterns in elementary school-age children?:

Research using the National Health and Nutrition Examination Survey, 2005-2010

Does television viewing affect weight status and dietary intake patterns in elementary school-age children? Research using the National Health and Nutrition Examination Survey, 2005-2010

E. Whitney Evans[1], Paul F. Jacques[1,2], Gerard E. Dallal[1,2], Jennifer Sacheck[1], Aviva Must[1,3]

[1]Tufts University, Friedman School of Nutrition Science and Policy (EWE, JS)
[2]Tufts University, Jean Mayer USDA Human Nutrition Research Center on Aging (PFJ, GED)
[3]Tufts University, School of Medicine (AM)

<u>Corresponding author (no reprints requested):</u>
E. Whitney Evans
136 Harrison Ave, Rm 128
Boston, MA 02111
(P) 617-636-3852; (F) 617-636-4017

Funding: This study was supported by NIDDK46200 (Boston Nutrition Obesity Research Center). E. Whitney Evans receives support from the NIDDK T32 Research Training Program in Nutrition and Chronic Disease.

Keywords: Television, Childhood Obesity, Snacks, Energy Intake, Diet Quality

Word Count:

Abstract: 198
Manuscript: 2,486

ABSTRACT

Background: Research suggests television (TV) time affects weight status and dietary intake in children; however, how TV time affects eating frequency in children is not clear.

Objective: To determine if TV time is associated with weight status, eating frequency, total energy intake and diet quality, measured by the Healthy Eating Index-2010, in elementary school-age children.

Design: Nationally representative data from 2,307 subjects, 6-11 years, who participated in the National Health and Nutrition Examination Survey, 2005-2010.

Outcome Measures: Daily TV time was measured by proxy-completed questionnaire.

Results: Each additional hour of daily TV viewing was statistically significantly associated with 1.18 times of odds of being overweight or obese (OR: 1.18, 95% CI: 1.09 to 1.27) and 0.71 unit decrease in total diet quality (p=0.003) (HEI-2005 range: 14.1 to 83.9 units). The relationships of TV viewing with eating frequency and with total energy intake, in separate models, were not statistically significant.

Conclusions: Daily TV viewing is not associated with eating frequency, but is positively associated with weight status and inversely associated with diet quality in elementary school-age children. Further research is needed to understand how daily TV viewing affects attention to dietary intake, particularly hunger and satiety cues in children.

INTRODUCTION

The first study to examine the relationship between television (TV) viewing and childhood obesity, was published in 1985 and concluded that TV viewing may cause obesity in some children (1). Over the subsequent 30 years, children in the United States have increased TV viewing by one hour per day (2, 3), and the obesity prevalence almost tripled (4). Estimates suggest that children currently watch as many as 4.5 hours of TV per day (2), which is more than twice the American Academy of Pediatrics' (AAP) recommendation to limit total screen time to fewer than 2 hours per day (5, 6). TV is considered an established risk factor for childhood overweight and obesity given that it is a sedentary behavior and is associated with poor dietary intake (7, 8). Specifically, TV viewing is positively associated with total caloric intake (9-11), consumption of energy dense snack foods (12, 13) and sugar-sweetened beverages (10, 13), and inversely associated with fruit and vegetable consumption (13-16).

As the single largest media source of food messaging (13), it is important to understand how TV viewing affects dietary intake patterns in children. One mechanism by which TV viewing has been shown to affect dietary intake is through food advertising. The expert panel convened by the Institute of Medicine to review the relationship between food advertising and children's diets concluded that food marketing *is* effective inasmuch as TV advertising influences food preference and purchase requests (17). Distracted or passive eating that may occur during TV viewing represents a second pathway through which TV viewing could influence intake (7). This hypothesis has been less well explored; however, overweight and obese teens report 'unconsciously' eating foods high in sugar, salt and fat while watching TV (18). Further indirect support for this plausible mechanism is national trend data which suggest a parallel increase between TV viewing and eating frequency in children. Accordingly, distracted or passive eating associated with TV viewing may be responsible for the observed increase in eating frequency (19).

This study was undertaken to better understand how TV time is related to weight status and dietary intake patterns in a nationally representative sample of school-age children. We used data from children, ages 6-11 years, who participated in the National Health and Nutrition Examination Survey (NHANES) 2005-2010, to explore the relationship of TV viewing with overweight and obesity, eating frequency, total energy intake and diet quality, as measured by the Healthy Eating Index, 2005 (HEI-2005). We hypothesized that TV viewing would be positively associated with overweight and obesity, eating frequency and total energy intake, and inversely associated with diet quality.

SUBJECTS & METHODS

Study Design and Participants

NHANES, conducted by the National Center for Health Statistics (NCHS), is a continuous survey program designed to assess the health and nutritional status of adults and children in the United States. To achieve a nationally representative sample, NCHS utilizes a complex, multistage, probability sampling design (20). Demographic, physiological, and dietary data are collected through a health interview and physical exam. A complete description of data-collection methods and analytic guidelines has been detailed elsewhere (20). Data from three continuous NHANES cycles, 2005-2006, 2007-2008, and 2009-2010, were combined for this analysis. Participants were included if they were 6-11 years of age, provided a complete and reliable in-person 24-hour recall, and had TV use information. This yielded an analytic sample size of 2,307 participants. The Institutional Review Board of Tufts University approved this study as non-human subjects research per federal guidance (21).

Dietary Exposures

As part of the NHANES protocol, an in-person, parent- or guardian-assisted 24-hour diet recall was collected from each participant by a trained interviewer during the Mobile Examination Center (MEC) examination. The 24-hour diet recall is collected using the United States Department of Agriculture (USDA) Automated Multiple Pass Method (AMPM) (22), which has been validated for energy using the doubly-labeled water technique (23). For all three cycles of NHANES, participants completed two 24-hour recalls; however, our analyses suggest that there may be systematic bias in reporting of eating frequency in children and adolescents resulting from mode of administration used to collect the two recalls (in-person vs. by telephone) (Appendix C). Accordingly, we used data from the in-person recall only.

Eating Frequency: Eating frequency was operationalized as the number of daily eating occasions reported by each participant during the in-person 24-hour diet recall. An eating occasion was defined as any distinct time when a respondent reported consuming at least one food or beverage item, *excluding water*. Eating occasion names were chosen by participants from a pre-defined list including, “breakfast, lunch, dinner, supper, brunch, snack, extended consumption, drink” for English speaking participants or “desayano, almuerzo, comida, merienda, cena, entra comida, botana, bocadillo, tentempie” for Spanish speaking participants. All eating occasions identified as “extended consumption" were combined into a single eating occasion with the original meal or snack at which consumption was initiated.

Total Energy Intake: Total energy intake was determined for each participant using the Total Nutrients File for the in-person 24-hour diet recall.

HEI-2005 Score: The HEI-2005 measures overall diet quality through adherence to the 2005 Dietary Guidelines for Americans (DGA) (24). We used the HEI-2005, rather than the HEI-2010, because the 2005 DGA were the only federal dietary guidance during the period of data collection for the three NHANES surveys used in this analysis. The HEI-2005 total score represents the sum of 12 nutrient- and food-based component scores and reflects whether intake of food groups and nutrients meet the standards set by the 2005 DGA. Nine of the components (fruit, whole fruit, total vegetables, dark green and orange vegetables, total grains, whole grains, milk, meat and beans, and oils) represent adequacy components for which a higher score indicates greater consumption, whereas the saturated fat, sodium, and energy from solid fat, alcohol, and added sugars (SoFAAS) represent moderation components where a higher score reflects lower consumption. Because the standards used to assign maximum HEI-2005 scores for each component are based on overall population needs and that elementary school-age children require a more nutrient-dense diet to achieve recommended intakes without exceeding energy needs, the HEI-2005 standards have been modified (25). Specifically, using mean Estimated Energy Requirements published by the Institute of Medicine for children ages 6-11 years, the HEI-2005 standards were modified according to the 1,800 calorie MyPyramid eating pattern (24-26). Total and component HEI-2005 scores were determined for each participant using the MyPyramid Equivalents Database (27), the 2003-2004 addendum (28), and SAS code made publically available by the USDA (29).

Outcome Measures

TV Viewing: Time spent watching TV was assessed by questionnaire across all three cycles of NHANES 2005-2010. Specifically, parents or guardians, serving as proxy-respondents, were asked, on average, over the past 30 days, how many hours per day their child sat and watched television.

Covariates

Age in months, sex, race/ethnicity, poverty-to-income ratio (PIR), and physical activity were considered as potential covariates. Race/ethnicity was coded by NCHS by combining information on race and Hispanic origin. Per guidance from NCHS, racial/ethnic categories include non-Hispanic white, non-Hispanic black, Mexican American, and other (30). Poverty-to-Income Ratio (PIR), which is the ratio of household income to the appropriate poverty threshold for the household size, was used as the primary measure of socioeconomic status. Finally, physical activity was assessed by questionnaire across all three cycles of NHANES 2005-2010. The questionnaire items used to collect physical activity information in children ages 6 to 11 years old changed between the 2007-2008 and 2009-2010 surveys. In the 2005-2006 and 2007-2008 surveys, proxy respondents were asked to report the number of times per week their child played or exercised hard. In 2009-2010, proxy respondents were asked the number of days per week that their child was physically active for at least 60 minutes over the past seven days.

Statistical Analyses:

Proc Survey procedures in SAS (Version 9.2, 2008, SAS Institute, Cary, NC) were used to obtain descriptive and inferential statistics while accounting for the complex, multistage, probability sampling methodology used to collect the 2005-2010 NHANES cycles. All tests were performed at the two-sided 0.05 level of significance. Sample weights, which account for survey non-response, over-sampling, post-stratification, and sampling error for each two-year survey, were re-scaled to represent the population at the midpoint of the combined six year survey period (20). The relationship of TV viewing with overweight and obesity status was estimated using logistic regression. The associations of TV viewing with eating frequency, total energy intake and diet quality were estimated using multivariable linear regression. Given its distribution, total energy intake was log-transformed; geometric means are reported. For each respective outcome, we assessed the need to control for each potential covariate: age in months, sex, race/ethnicity, PIR, and reported physical activity level. To account for the change in physical activity assessment across survey cycles, dummy variables were created for survey cycle and physical activity, and interaction terms were included in the full multivariate models. Potential covariates were retained in each respective model if their inclusion induced a change in the point estimate greater than 10% (31).

RESULTS

A total of 2,307 children, 6 to 11 years of age, provided a complete and reliable in-person 24-hour recall, and their proxy provided data on hours spent watching TV daily. The characteristics of this sample are shown in **Table 1**. On average, the participants in this sample were 8.5 years of age, were active six days per week, and 32.5% were overweight or obese. Data in **Table 2** show differences in TV viewing, eating frequency, total energy intake and diet quality between children whose proxy-reported daily TV viewing is consistent with the AAP recommendation to limit TV time to less than 2 hours per day and those whose proxy-reported TV viewing exceeds the recommendation. On average, children who exceed the AAP guidelines watch more than three additional hours of TV daily ($p<0.0001$). Further, with respect to dietary intake patterns, children who exceed the AAP guidelines report consume a lower quality diet than those who adhere to the recommendation ($p<0.001$). No statistically significant differences were observed between groups for eating frequency or total daily energy intake.

Table 3 displays the results from crude and multivariable regression models for each dependent variable: weight status, eating frequency, total energy intake and diet quality. For each additional hour of daily TV viewing, children have 18% greater odds of being overweight or obese (OR: 1.18, 95% CI: 1.09 to 1.27) after controlling for physical activity. Although a positive relationship between daily TV viewing and weight status was observed, the relationships of TV viewing with eating frequency and total energy intake, in separate models, were not statistically significant. Total HEI-2005 scores ranged from 14.1 to 83.9 out of a possible 100 in this nationally representative sample. TV viewing was statistically significantly and inversely associated with total HEI-2005 scores. Specifically, for each additional hour of daily TV viewing, a child's HEI-2005 total score decreased by 0.71 units ($p=0.003$).

DISCUSSION

This study was done to explore whether TV viewing is associated with weight status, eating frequency, total energy intake, and diet quality in a nationally representative sample of 6-11 year old children. We hypothesized a positive association of TV viewing with weight status, eating frequency and energy intake and an inverse association with diet quality. As anticipated, we observed a statistically significant and positive association between TV viewing and weight status and an inverse association between TV viewing and diet quality. However, the observed null relationship of TV viewing with eating frequency and with total energy intake was unexpected.

Our results are consistent with studies over three decades which have replicated Dietz and Gortmaker's initial finding that TV viewing is positively associated childhood obesity (1). Since then, prospective studies have shown that TV viewing is a risk factor for weight gain (32), as have randomized controlled trials (33, 34), the gold standard of study designs. After reducing TV time through intervention, Epstein and colleagues observed weight loss in children ages 8-12 years old (33). Robinson *et al.* found that in children who continued to watch TV at their regular rate, adiposity significantly increased over a school year compared to those who decreased TV viewing by 40% (34). Our results are also consistent with other studies which have examined the relationship between TV viewing and diet quality. In a sample of fourth, fifth and six graders, with an average age of 10 years, TV viewing was associated with higher consumption of pizza, salty snacks and sugar-sweetened beverages and lower consumption of fruits and vegetables (13). Similarly, in sixth to eighth graders, Wiecha and colleagues found that each additional hour of TV viewing was positively associated with consumption of energy dense snack foods, fast food, and sugar-sweetened beverages (35). Our findings add to this literature through the use of a comprehensive diet quality score, as provided by the HEI-2005, in suggesting that overall diet quality decreases by nearly 1 unit with each additional hour of daily TV viewing.

That we did not find a statistically significant relationship of TV viewing with eating frequency or with total energy intake was unexpected. There are several possible explanations for the observed null findings. First, if food consumption during TV time is truly distracted or passive, as we hypothesized, eating occasions that occur while watching TV may not be accurately reported in the context of a 24-hour diet recall. A study examining the relationship between weight status and attention paid to the media, found that children whose primary attention was focused on the TV had higher BMI than those who paid less attention to the TV (36). The authors attribute their findings to 'distracted' eating, suggesting that attention paid to the TV distracts young people from physiologic hunger and satiety signals.

This study had some noteworthy limitations. First, TV viewing was reported by parents or guardians such that it is only valid to the extent that the parent or guardian is able to monitor or otherwise confirm TV use. Second, we were only able to consider TV time rather than total screen time. Two recent studies reported positive associations between video game play and snacking, despite no changes in appetite (37, 38). Despite these limitations, this analysis also had strengths. First, this study was done in a nationally representative sample of 2,307 children all of which had measured heights and weights. Second, the dietary data were collected using the validated USDA's AMPM.

CONCLUSIONS

It is well established that TV viewing is a modifiable risk factor for childhood overweight and obesity. This association is likely due both to fact that TV viewing is a sedentary behavior associated with poor dietary intake. Our cross-sectional analyses support the notion that TV viewing is positively associated with weight status and inversely associated with diet quality. While this analysis did not identify a statistically significant relationship between TV viewing and eating frequency, this may reflect under-reporting related to the distracted eating that may occur with TV viewing. Accordingly, future research studies using objective measures of total TV time and eating frequency, are needed to better understand how TV viewing affects attention to dietary intake, particularly hunger and satiety cues in children.

REFERENCES

1. Dietz WH, Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. *Pediatrics*. 1985;**75**(5):807-812.

2. Rideout V, Foehr U, Roberts D. Generation M2: Media in the lives of 8- to 18-year olds. Menlo Park, CA: Kaiser Family Foundation, 2010.

3. Neilsen Report on Television. Northbrook, IL: A.C. Neilsen Co, 1983.

4. Ogden CL, Carroll MD, Curtin LR. Prevalence of high body mass index in US children and adolescents, 2007-2008. *J Am Med Assoc*. 2010;**303**(3):242-249.

5. Barlow SE. Expert committee recommendations regarding the prevention, assessment and treatment of child and adolescent overweight and obesity: summary report. *Pediatrics*. 2007;**120**:S164-S192.

6. American Academy of Pediatrics Committee on Communications. Children, adolescents, and television. *Pediatrics*. 1995;**96**(4):786-787.

7. Ebbling CB, Pawlak DB, Ludwig DS. Childhood obesity: public health crisis, common sense cure. *Lancet*. 2002;**360**:473-482.

8. French SA, Story M, Jeffery RW. Environmental influences on eating and physical activity *Annu Rev Public Health*. 2001;**22**(1):309-335.

9. Temple JL, Giacomelli AM, Kent KM, Roemmich JN, Epstein LH. Television watching increases motivated responding for food and energy intake in children. *Am J Clin Nutr*. 2007;**85**(2):355-361.

10. Miller SA, Taveras EM, Rifas-Shiman SL, Gillman MW. Association between television viewing and poor diet quality in young children. *Int J Pediatr Obes*. 2008;**3**(3):168-176.

11. Sonneville KR, Gortmaker SL. Total energy intake, adolescent discretionary behaviors and the energy gap. *Int J Obes*. 2008;**32**(S6):S19-S27.

12. Boyland EJ, Harrold JA, Kirkham TC, Corker C, Cuddy J, et al. Food commercials increase preference for energy-dense foods, particularly in children who watch more television. *Pediatrics*. 2011;**128**(1):e93-e100.

13. Coon KA, Goldberg J, Rogers BL, Tucker KL. Relationships between use of television during meals and children's food consumption patterns. *Pediatrics*. 2001;**107**(1):e7.

14. Harris JL, Bargh JA, Brownell KD. Priming effects of television food advertising on eating behavior. *Health Psychol*. 2009;**28**(4):404-413.

15. Coon J, Goldberg J, Rogers B, Tucker K. Relationships between use of television during meals and children's food consumption patterns. *Pediatrics*. 2001;**107**:e7.

16. Pearson N, Biddle SJH. Sedentary behavior and dietary intake in children, adolescents, and adults: A systematic review. *Am J Prev Med*. 2011;**41**(2):178-188.

17. Institue of Medicine. Preventing Childhood Obesity: Health in the Balance. Koplan JP, Liverman CT, Kraak VA, editors: The National Academies Press; 2005.

18. Rich M, Patashnick J, Huecker D, Ludwig D. Living with obesity: Visual narratives of overweight adolescents. *J Adolesc Health*. 2002;**30**(2):100.

19. Popkin BM, Duffy KJ. Does hunger and satiety drive eating anymore? Increasing eating occasions and decreasing time between eating occasions in the United States. *Am J Clin Nutr*. 2010;**91**:1342-1347.

20. Continuous NHANES Web Tutorial [database on the Internet]. Center for Disease Control and Prevention. 2009 [cited September 13, 2011]. Available from: http://www.cdc.gov/nchs/tutorials/Nhanes/index_continuous.htm.

21. U.S. Department of Health and Human Services. Basic HHS Policy for Protection of Human Research Subjects. 2009 [cited 2012 November 27]; Available from: http://www.hhs.gov/ohrp/humansubjects/guidance/45cfr46.html.

22. National Center for Health Statistics. Key Concepts About NHANES Dietary Data Collection. 2010 [cited 2011 September 12]; Available from: http://www.cdc.gov/nchs/tutorials/dietary/SurveyOrientation/DietaryDataOverview/Info2.htm.

23. Moshfegh A, Rhodes D, Baer D, Murayi T, Clemens J, Rumpler W, et al. The US Department of Agriculture Automated Multiple-pass Method reduces bias in the collection of energy intakes. *Am J Clin Nutr*. 2008;**88**(2):324-332.

24. Guenther P, Reedy J, Krebs-Smith S. Development of the Healthy Eating Index-2005. *J Am Diet Assoc*. 2008;**108**(11):1896-1901.

25. Fox MK, Clark MA, Condon E, Wilson A. Diet quality of school-age children in the U.S. and association with participation in the school meal programs. Cambridge, MA: Mathematica Policy Research, Inc, 2010 Contract No.: 6436-005.

26. Institue of Medicine. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington, DC: National Academies Press; 2005. Available from: http://www.nal.usda.gov/fnic/DRI/DRI_Energy/energy_full_report.pdf.

27. MyPyramid Equivalents Database, 2.0 for USDA Survey Foods, 2003-2004 [database on the Internet]. Beltsville Human Nutrition Research Center, Agricultural Research Service, USDA. 2003-2004 [cited September 11, 2012]. Available from: http://www.ars.usda.gov/services/docs.htm?docid=17558.

28. Koegel K, Kuczynski K. Addendum to the MyPyramid Equivalents Database 2.0. Alexandria, VA: USDA Center for Nutrition Policy and Promotion, Nutrition Guidance and Analysis Division,; 2011 [cited 2012 November 11]; Available from: http://www.cnpp.usda.gov/OtherProjects.htm.

29. United States Department of Agriculture. Healthy Eating Index-2005 Development and Evaluation Technical Report Support Files. 2010 [cited 2011 September 13]; Available from: http://www.cnpp.usda.gov/HealthyEatingIndex-2005report.htm.

30. National Center for Health Statistics. Analytic Note Regarding 2007-2010 Survey Design Changes and Combining Data Across other Survey Cycles 2011 [cited 2011 Septmeber 13]; Available from: http://www.cdc.gov/nchs/data/nhanes/analyticnote_2007-2010.pdf.

31. Rothman K, Greenland S, Lash T. Modern Epidemiology. Third ed. Philadelphia: Lippincott Williams & Wilkins; 2008.

32. Hancox RJP, R. Watching television is associated with childhood obesity: But is it clinically important? *Int J Obes (Lond)*. 2006;**30**:171-175.

33. Epstein LH, Paluch RA, Gordy CC, Dorn J. Decreasing sedentary behaviors in treating pediatric obesity. *Arch Ped Adolesc Med*. 2000;**154**:220-226.

34. Robinson T. Reducing children's television viewing to prevent obesity: a randomized controlled trial. *J Am Med Assoc*. 1999;**282**:1561-1567.

35. Weicha J, Peterson K, Ludwig D, Kim J, Sobol A, Gortmaker S. When children eat what they watch: impact of television viewing on dietary intake in youth. *Arch Pediatr Adolesc Med*. 2006;**160**(4):436-442.

36. Bickham D, Blood E, Walls C, Shrier L, Rich M. Characteristics of screen media use associated with higher BMI in young adolescents. *Pedatrics*. 2013;**131**(5):1-7.

37. Chaput J-P, Visby T, Nyby S, Klingenberg L, Gregersen NT, Tremblay A, et al. Video game playing increases food intake in adolescents: a randomized crossover study. *The American Journal of Clinical Nutrition*. 2011;**93**(6):1196-1203.

38. Cessna T, Raudenbush B, Reed A, Hunker R. Effects of video game play on snacking behavior. *Appetite*. 2007;**41**(1):282.

39. Feskanich D, Rockett HRH, Colditz GA. Modifying the healthy eating index to assess diet quality in children and adolescents. *Journal of the American Dietetic Association*. 2004;**104**(9):1375-1383.

40. Fox MK, Clark M, Condon E, Wilson A. Diet Quality of School-Age Children in the U.S. and Association With Participation in the School Meal Programs. 2010 Contractor and Cooperator Report No. 59.

TABLES

Table 1. Sample characteristics for elementary school-age children, 6-11 years, who participated in the National Health and Nutrition Examination Survey, 2005-2010

	NHANES 2005-2010 Participants (6-11 years old)[1]
Age (mean (95% CI))	8.48 years (8.40 to 8.56)
Sex (% female)	48.9%
Race-Ethnicity	
Non-Hispanic White	57.3%
Non-Hispanic Black	14.2%
Mexican-American	14.6%
Other	13.9%
Poverty-to-Income Ratio (PIR)	
PIR < 1.30	34.3%
1.30 < PIR < 3.50	36.0%
PIR $\geq$ 3.50	29.7%
Physical Activity[2] (mean (95% CI))	
2005-2008 NHANES Cycles	6.00 times per week (5.70 to 6.28)
2009-2010 NHANES Cycle	6.03 days per week (5.74 to 6.33)
Weight Status[3] (%)	
Underweight	3.1%
Normal	64.3%
Overweight or Obese	32.5%

[1] Children ages 6 to 11 years with one reliable 24 hour diet recall and complete TV use data

[2] The questionnaire item for physical activity assessment changed for children ages 6-11 years between NHANES 2005-2008 and 2009-2010. Proxy respondents were asked the 'number of times' versus 'number of days' their child played or exercised hard over the last week in 2005-2008 and 2009-2010, respectively.

[3] Underweight: BMI < 5^{th} percentile for sex and age; Normal: BMI $\geq 5^{th}$ percentile and $<85^{th}$ percentile for sex and age; Overweight or Obese: BMI $\geq 85^{th}$ percentile for sex and age

Table 2. Mean reported television (TV) viewing time, eating frequency, total energy intake, and diet quality in elementary school-age participants from NHANES 2005-2010, by adherence to American Academy of Pediatrics (AAP) TV viewing guidelines[1]

	Adhered to AAP guidelines[1] (n=1218)	**Exceeded AAP guidelines[2]** (n=1089)	**T-Test (p-value)[3]**
	Mean (95% CI)		
Number of daily hours of TV viewing	0.71 (0.66 to 0.75)	3.76 (3.66 to 3.87)	t=56.9 ($p<0.0001$)
Number of daily eating occasions	5.3 (5.1 to 5.4)	5.2 (5.1 to 5.3)	t=0.61 ($p=0.54$)
Total energy intake (kcals/day)[1]	1901.4 (1845.3 to 1957.6)	1960.2 (1902.5 to 2017.9)	t=1.47 ($p=0.15$)
Diet Quality[2]	47.2 (46.2 to 48.2)	44.5 (43.3 to 45.6)	t=3.77 ($p<0.001$)

[1] The AAP recommends that children ages 2 years and older limit TV time to two hours per day
[2] Geometric mean reported as total energy intake was log transformed
[3] Determined by Healthy Eating Index-2005 total score (range 14.1 to 83.9 out of a possible 100)
[4] t-Test statistics and p-values estimated using Proc SurveyReg

Table 3. Associations of TV viewing with eating frequency, total energy intake, and diet quality in elementary school-age participants from the National Health and Nutrition Examination Survey, 2005-2010

Outcome	Crude Model Estimates	Adjusted Model Estimates
	Odds Ratio (95% CI)	
Overweight & Obesity[1]	1.19 (1.10 to 1.29)	1.18 (1.09 to 1.27)
	Beta-estimate (p-value)	
Eating Frequency[2]	-0.037 (p=0.16)	-0.001 (p=0.97)
Total Energy Intake[3]	0.0078 (p=0.17)	0.0085 (p=0.18)
Diet Quality[4]	-0.83 (p=0.007)	-0.71 (p=0.003)

[1]Logistic regression model adjusted for physical activity
[2]Multivariable linear regression model adjusted for race/ethnicity and poverty-to-income ratio
[3]Multivariable linear regression estimating model effects for log-transformed total energy intake. Adjusted model controls for sex, age-in-years, race/ethnicity, poverty-to-income ratio, and physical activity
[4] Multivariable linear regression model adjusted for poverty-to-income ratio

Chapter Seven

Summary and Discussion

Chapter Seven: Summary and Discussion

The expert committee that authored *The Report of the Dietary Guidelines Advisory Committee on Dietary Guidelines for Americans, 2005*, identified a better understanding of the relationship between the eating frequency and weight as a research priority. They write "It is important in designing strategies for managing body weight to have a better understanding of the role of pattern of food intake on body adiposity"(1). This thesis was conceptualized to clarify the literature, in effort to provide guidance as to an ideal meal and snack pattern in children. At the outset of this research, two mechanisms by which eating frequency could be related to weight in children were considered. First, as we hypothesized, eating more frequently would increase exposure to low nutrient, energy-dense foods, and thereby increase energy intake, decrease diet quality, and lead to a positive association between eating frequency and weight gain. Second, increased eating frequency may help *regulate* energy intake through increased metabolism, reduced hunger, and improved glucose and insulin control; this would result in an inverse association between eating frequency and weight gain. We also examined how TV viewing may affect eating frequency as a potentially relevant environmental factor.

Several epidemiologic studies provide evidence in support of an inverse association between eating frequency and weight in children (2-5), whereas only a few support a positive association (6, 7). However, the observed inverse cross-sectional association may be an artifact biased dietary recall (8-10). This dissertation was uniquely poised to address this assertion as the cross-sectional relationship between eating frequency and weight were examined using dietary and anthropometric data from

NHANES and the Daily D sub-study. Further, the prospective relationship of eating frequency with change in BMIz at 6 months and 1 year was also examined within the Daily D diet sub-study, which allowed for direct comparison between cross-sectional and prospective findings.

NHANES

Trend data show that several eating behaviors including increased portion size, increased snacking prevalence and eating more meals away from home have all coincided with the increase in total energy intake over the past three decades among children (11, 12). With respect to snacking, nationally representative data show that 98% of children consume a snack daily, snacks contribute 27% of total daily energy, and the main energy sources in snacks include desserts, salty snacks, and SSBs (12). Given these findings, we hypothesized that eating frequency, operationalized as the number of daily eating occasions, would be positively associated with total energy intake, inversely associated with diet quality, and, thus, associated with greater odds of overweight and obesity. The results of these analyses were contrary to our hypothesis, however, and somewhat perplexing given the observed inverse association between eating frequency and obesity in elementary school-age children and adolescents despite a positive association between reported daily eating frequency and total energy intake. We also found that eating frequency is positively associated with diet quality in elementary school-age children and adolescents.

There are a few possible explanations for these paradoxical findings. First, as always, the observed inverse relationship between eating frequency and weight status could be a chance finding. This is unlikely, however, given that our results are consistent with most cross-sectional studies in children and adolescents (9, 13, 14). Second, it is also possible that the observed inverse association in elementary school-age children and adolescents is due to the cross-sectional study design of NHANES. Other researchers have suggested that the reported inverse relationship between eating frequency and relative weight in children is an artifact of biased dietary recall or under-reporting of eating frequency by children who are overweight or obese (8-10, 15). Third, the observed findings could reflect the interplay between eating patterns and physical activity. Specifically, children who are more physically active may consume more total energy over an increased number of daily eating occasions, yet weigh less due to increased energy expenditure. Our multivariate models do not support this assertion, as the addition of physical activity to the regression model did not affect the odds of being overweight or obese according to eating frequency. It is not possible, however, to rule out residual confounding by physical activity given the methodology used to assess physical activity in NHANES. Given the many limitations of using cross-sectional data to examine relationships between diet and obesity, the NHANES results should not be interpreted to suggest that eating more frequently results in a lower weight, particularly given that we observed a statistically significant and positive relationship between eating frequency and total energy intake. Rather, these results highlight the need for prospective studies designed to elucidate factors that influence both eating frequency and how eating frequency may affect weight gain in children and adolescents.

Daily D

The Daily D dietary sub-study examined both the cross-sectional and prospective relationships between eating frequency and weight in school-age children and adolescents. We hypothesized that eating frequency would be positively associated with total energy intake, inversely associated with diet quality and positively associated with BMIz at baseline and with change in BMIz at 6-months and 1-year. Similar to our analysis within NHANES, the cross-sectional relationship between eating frequency and weight at baseline was statistically significant and inverse. However, by 6-months, the nature of the relationship changed such that eating frequency was statistically significantly and *positively* related to change in BMIz. These results, considered with the findings that eating frequency was statistically significantly and positively associated with total energy intake, and snacking was positively associated with diet quality in elementary school age children and inversely associated with diet quality in adolescents, support the notion that the observed inverse, cross-sectional relationships between eating frequency and weight is likely due to methodological limitations of the cross-sectional study design (8, 16).

NHANES: TV viewing and eating frequency

To extend our research into possible mechanisms by which eating frequency may affect weight in children, we examined whether TV viewing was associated with weight status, eating frequency, total energy intake, and diet quality using dietary, TV use, and anthropometric data from 6-11 year old children who participated in NHANES, 2005-2010. We hypothesized that TV viewing would be positively associated with weight status, eating frequency and energy intake and an inversely associated with diet quality. As anticipated, we observed a statistically significant and positive association between TV viewing and weight status and an inverse association between TV viewing and diet quality. However, the observed null relationships of TV viewing with eating frequency and total energy intake were unexpected. The most likely explanation for these null findings is under-reporting of eating frequency and total energy intake. Specifically, if food consumption during TV time is truly distracted or passive, as we hypothesized, it is possible that eating occasions that occur while watching TV may not be accurately reported in the context of a 24-hour diet recall. This assertion is supported by a recent study which examined the relationship between weight status and attention paid to electronic Media (17). Children whose primary attention was focused on the TV had higher BMI than those who paid less attention to the TV. The authors attribute their findings to 'distracted' eating that attention paid to the TV distracts young people from physiologic hunger and satiety signals (17). Overall, these findings suggest that further research is needed to better understand how TV viewing affects attention to dietary intake, particularly hunger and satiety cues in children.

Conclusions

The purpose of this work was three-fold. First, we sought to provide clarity to an otherwise equivocal body of literature by examining the cross-sectional relationship between eating frequency and weight and the prospective relationship between eating frequency and weight gain. Second, we anticipated providing insight into possible mechanisms by which eating frequency may affect weight status in children by examining the relationships of eating frequency with total energy intake, diet quality and TV viewing. Finally, we wanted this work to help parents, schools and clinicians better understand what eating pattern, if any, can help minimize excess weight gain in childhood at different stages of the pediatric life course. Performing parallel analyses in two separate data sets with different study designs, uniquely allowed us to compare cross-sectional and prospective findings. In their entirety, our results provide some clarity to the literature. The discrepancy between our cross-sectional and prospective findings suggests that under-reporting of eating frequency by overweight or obese children may be responsible for the equivocal literature. Our findings align with assertions made by Bellisle and colleagues, Huang and colleagues, and Crawley and Summerbell that the observed statistically significant relationship between eating frequency and decreased weight is likely an artifact of biased dietary recall (8, 9, 15). This conclusion is reinforced by the observed positive relationship between reported daily eating frequency and total energy intake.

Given that prevention of childhood obesity is a public health priority, we anticipated that this work would provide insight into an ideal meal and snack pattern designed to minimize excess weight gain in childhood. Unfortunately, however, this body of work does not suggest that a single meal and snack pattern is ideal, particularly given that the relationships of eating frequency with relative weight and diet quality differed between pediatric life stage groups. Instead, overall findings demonstrate the need for future prospective work designed to assess the relationship between *usual* eating frequency and long-term weight gain in children. In the absence of statistical methods to model usual eating frequency, 24-hour recalls should be collected more frequently in future work to provide better estimates of usual behaviors so that true longitudinal analyses can be used. In the meantime, given our the positive association between eating frequency and total energy intake, there is a critical need to address consumption of low-nutrient, energy-dense foods and beverages, particularly as snacks, given that these foods do not help children meet dietary recommendations and have the potential to increase energy intake. Snacking has become a pervasive behavior among children; interventions that effectively promote the consumption of healthy snacks may reduce excess weight gain in childhood.

REFERENCES

1. USDA, US Department of Health and Human Services. Report of the Dietary Guidelines Advisory Committee of the Dietary Guidelines for Americans, 2010. 2010 [cited 2013 January 11]; Available from: http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm.

2. Lioret S, Touvier M, Lafay L, Volatier JL, Maire B. Are eating occasions and their energy content related to child overweight and socioeconomic status? *Obesity* 2008;**16**:2518-2523.

3. Ritchie LD. Less frequent eating predicts greater BMI and waist circumference in female adolescents. *Am J Clin Nutr*. 2012;**95**(2):290-296.

4. Toschke A, Kuchenhoff H, Koletzko B, von Kries R. Meal frequency and childhood obesity. *Obes Res*. 2005;**13**(11):1932-1938.

5. Fabry P, Hejda S, Cerny K, Osancova MA, Pechar J. Effect of meal frequency in schoolchildren. *Am J Clin Nutr*. 1966;**18**:358-361.

6. Thompson OM, Ballew C, Resnicow K, Gillespie C, Must A, Bandini L, et al. Dietary pattern as a predictor of change in BMI z-score among girls. *Int J Pediatr Obes*. 2006;**30**:176-182.

7. Isacco L, Lazaar N, Ratel S, Thivel D, Aucouturier J, Doré E, et al. The impact of eating habits on anthropometric characteristics in French primary school children. *Child Care Health Dev*. 2010;**36**(6):835-842.

8. Bellisle F, McDevitt R, Prentice A. Meal frequency and energy balance. *1997*. 1997;**77**(Suppl. 1):S57-S70.

9. Huang TT-K, Howarth NC, Lin B-H, Roberts SB, McCrory MA. Energy intake and meal portions: associations with BMI percentile in U.S. children. *Obes Res*. 2004;**12**(11):1875-1886.

10. Summerbell C, Moody RC, Shanks J, Stock MJ, Geissler C. Relationship between feeding pattern and body mass index in 220 free-living people in four age groups. *Eur J Clin Nutr*. 1996;**50**(8):513-519.

11. Piernas C, Popkin BM. Increased portion sizes from energy-dense foods affect total energy intake at eating occasions in US children and adolescents: patterns and trends by age group and sociodemographic characteristics, 1977-2006. *Am J Clin Nutr*. 2011.

12. Piernas C, Popkin BM. Trends in snacking among U.S. children. *Health Aff*. 2010;**29**(3):398-404.

13. Kaisari P, Yannakoulia M, Panagiotakos DB. Eating frequency and overweight and obesity in children and adolescents: A meta-analysis. *Pediatrics*. 2013.

14. Zerva A, Nassis G, Krekoukia M, Psarra G, Sidossis L. Effect of eating frequency on body composition in 9-11 year old children. *Int J Sports Med*. 2007;**28**:265-270.

15. Crawley H, Summerbell C. Feeding frequency and BMI among teenagers aged 16-17 years. *Int J Obes Relat Metab Disord*. 1997;**21**(2):159-161.

16. McCrory MA, Campbell WW. Effects of eating frequency, snacking, and breakfast skipping on energy regulation: symposium overview. *J Nutr*. 2011;**141**:144-147.

17. Bickham D, Blood E, Walls C, Shrier L, Rich M. Characteristics of screen media use associated with higher BMI in young adolescents. *Pedatrics*. 2013;**131**(5):1-7.

Appendices

Table of Contents:

Appendix A

Additional Methods

Modification of the Healthy Eating Index, 2005

Appendix A:

Modification of the Healthy Eating Index, 2005

The standards for each HEI-2005 component score are derived to meet the nutrient needs of the overall U.S. population. With the exception of saturated fat and sodium, children typically need to consume larger amounts of most food groups and nutrients on a per calorie basis to achieve desired intakes without exceeding energy intake. Researchers have therefore questioned the use of the HEI-2005 in its current form (39). For example, in their analysis of data from the School Nutrition and Dietary Analysis (SNDA-III), Fox and colleagues modified the standards based on Estimated Energy Requirements (EER)(40). In this approach, EER for each pediatric life stage were determined using estimating equations developed by the Institute of Medicine. Given large discrepancies in energy needs for adolescent males and females, sex-specific criteria were developed for adolescents.. Mean EER's were 1,600 calories per day for preschool-age children, 1,800 calories per day for elementary school-age children, 2,000 calories per day adolescent females and 2,400 calories per day for adolescent males calories per day. Table 1 shows both the original HEI-2005 standards for each component score as well as the modified standards, which come from the MyPyramid eating patterns for each respective pediatric life stage group and are published by the USDA (24).

Table 1. Original and modified standards for the Healthy Eating Index, 2005 (HEI-2005)

HEI Component	Max Score	Original HEI-2005 Standards	Modified Standards			
			Preschool 1,600 kcals/day	Elementary 1,800 kcals/day	Adolescent Females 2,000 kcals/day	Adolescent Males 2,400 kcals/day
Total Fruit	5	≥ 0.8 cup	≥ 0.9 cup	≥ 0.8 cup	≥ 1.0 cup	≥ 0.8 cup
Whole Fruit	5	≥ 0.4 cup	≥ 0.4 cup	≥ 0.4 cup	≥ 0.5 cup	≥ 0.4 cup
Total Vegetables	5	≥ 1.1 cup	≥ 1.2 cup	≥ 1.4 cup	≥ 1.3 cup	≥ 1.3 cup
Dark Green Orange Vegetables and Legumes[1]	5	≥ 0.4 cup	≥ 0.5 cup	≥ 0.6 cup	≥ 0.5 cup	≥ 0.5 cup
Total Grains	5	≥ 3.0 oz.	≥ 3.1 oz.	≥ 3.3 oz.	≥ 3.0 oz.	≥ 3.3 oz.
Whole Grains	5	≥ 1.5 oz.	≥ 1.9 oz.	≥ 1.7 oz.	≥ 1.5 oz.	≥ 1.7 oz.
Milk[2]	10	≥ 1.3 cup	≥ 1.9 cup	≥ 1.7 cup	≥ 1.5 cup	≥ 1.3 cup
Meat and Beans	10	≥ 2.5 oz.	≥ 3.1 oz.	≥ 2.8 oz.	≥ 2.8 oz.	≥ 2.7 oz.
Oils[3]	10	≥ 12 gm.	≥ 14 gm.	≥ 13 gm.	≥ 14 gm.	≥ 13 gm.
Saturated Fat	10	≤ 7%	≤ 7%	≤ 7%	≤ 7%	≤ 7%
Sodium	10	≤ 0.7 gm.	≤ 0.7 gm.	≤ 0.7 gm.	≤ 0.7 gm.	≤ 0.7 gm.
SoFAAS[4]	20	≤ 20%	≤ 8.3%	≤ 11%	≤ 13.4%	≤ 15.1%
Total Score	100					

[1] Legumes are counted as vegetables only after the standard for intake of meat and beans is met
[2] Includes all milk products including milks, yogurt, and cheese
[3] Includes non-hydrogenated vegetable oils and oils in fish, nuts, and seeds
[4] Solid Fats, Alcohol and Added Sugars

Appendix B

Supplemental Paper:

Reported eating frequency varies by 24-hour recall mode of administration

in children ages 2-18 years who participated in the

National Health and Nutrition Examination Survey

Reported eating frequency varies by 24-hour recall mode of administration in children ages 2-18 years who participated in the National Health and Nutrition Examination Survey

E. Whitney Evans, MS, RD[1], Paul Jacques, PhD[2], Gerard E. Dallal, PhD[2], Jennifer Sacheck, PhD[1], Aviva Must, PhD[4]

[1] Tufts University Friedman School of Nutrition Science and Policy, 150 Harrison Ave, Boston, MA 02111
[2] Tufts University, Jean Mayer USDA Human Nutrition Research Center on Aging
[3] Tufts University School of Medicine, 136 Harrison Ave, Boston, MA 02111

KEY WORDS: Eating Frequency, Snacking, Children, Usual Intake, Dietary Assessment

Abstract Word Count: 250
Manuscript Word Count: 2250
Figures: 0
Tables: 2

Corresponding Author:
E. Whitney Evans MS, RD
Tufts University Friedman School of Nutrition Science and Policy
136 Harrison Avenue, Boston, MA 02111
(P) 617-636-3852 (F) 617-636-4017
whitney.evans@tufts.edu

ABSTRACT

The role of eating frequency in the development of childhood obesity has garnered a lot of attention. Over the last three decades, as the prevalence of childhood overweight and obesity has increased, eating frequency has increased by an average of 2.0 eating occasions/day. Despite this simultaneous rise, the relationship between eating frequency and childhood obesity is not well established. We examined eating frequency reported in repeat 24-hour recalls collected from children ages 2-18 years who participated in 2005-2010 National Health and Nutrition Examination Survey (NHANES) to determine if it differs according to day of the week, on weekend vs. weekdays, and by mode of administration for the 24-hour recalls (in-person versus over-the-telephone), to better understand how to best measure usual eating frequency in children. Results show that reported eating frequency does not differ by day of the week or between weekend and week days; however, on average, the number of eating occasions reported in-person is 0.5 occasions greater than that reported over-the-telephone ($p<0.001$). Further, linear regression analyses suggest that the estimates for eating frequency across the two 24-hour recalls are not in agreement. These findings highlight the need for further research to understand how differences in 24-hour recall collection methodology affect the report of eating occasions in children.

KEYWORDS: Eating Frequency, Snacking, Children, Usual Intake

INTRODUCTION

Given the current obesity epidemic, determining dietary risk factors that contribute to obesity in childhood and adolescence has been a focus of nutrition research. Increased eating frequency, particularly in the form of snacking, is one aspect of diet that has received attention. Over the last three decades, research shows that eating frequency in American children has considerably increased. The average eating frequency, operationalized as number of eating occasions per day, in children shifted from 3.0 in the late 1970's to 5.0 in 2006 (1). This increase is largely attributed to snacking behavior, as analyses of 2003-2006 NHANES data suggest that 98% of children consume at least one snack per day, while on average, children consume almost three snacks per day (2). Further, data from the third School Nutrition Dietary Assessment Study show that 40% of children consume a snack during the school day (3).

The concurrent increase in childhood obesity suggests that an increased eating frequency may contribute to childhood weight gain; however, the literature on this topic is equivocal (4). A few studies have found that greater eating frequency is associated with an increased odds of overweight in children (5, 6), while others have found an inverse relationship between eating frequency and weight status (7-9). These inconsistent findings may be due to the lack of a consistent definition for snacking (10); however, they may also be due to the manner in which eating frequency is measured and operationalized in these investigations.

For most epidemiologic studies exploring the association between diet and an outcome, particularly a long-term outcome like obesity, the primary exposure of interest is usual, or long-term, dietary intake given the day-to-day variation in diet (11). Food frequency questionnaires, which estimate usual intake over a longer period of time, are not designed to assess eating frequency. Therefore, most studies that examine eating frequency rely on data from 24-hour recalls, a method which captures intake on a single day but is susceptible to large amounts of within person variation (11). Currently, no accepted statistical methods are available to estimate usual eating frequency from repeat 24-hour recalls (12). Accordingly, most analyses examining the relationship between usual eating frequency and weight status have done so by averaging number of daily eating occasions across multiple 24-hour recalls or food records or relied on estimates from a single 24-hour recall (6, 13-16) despite the well-documented drawbacks of doing so (17).

To understand how to best characterize usual eating frequency in the absence of more sophisticated statistical methods, the purpose of this analysis was to examine if eating frequency reported in repeat 24-hour recalls collected as part of the continuous National Health and Nutrition Examination Survey (NHANES) 2005-2010, differs according to day of the week, on weekend vs. weekdays, and mode of administration (in-person versus over the telephone).

METHODS

Study Design and Participants

NHANES, collected by the National Center for Health Statistics (NCHS), is a continuous program of studies designed to cross-sectionally assess the health and nutritional status of adults and children in the United States. NCHS utilizes a complex, multistage, probability sampling design to create samples that are representative of the civilian, non-institutionalized US population (18). For purposes of this analysis, data from three continuous NHANES cycles, 2005-2006, 2007-2008, and 2009-2010 were combined. This dataset included dietary data from a total of 10,891 participants aged 2-18 years. Participants were excluded if they were missing anthropometric measurements, completed only one 24-hour recall, or provided unreliable dietary data. This yielded a sample size of 8,366.

Dietary Assessment Measures

Within the *What We Eat in America* protocol, the dietary component of NHANES, two non-consecutive 24-hour recalls are collected by trained dietary interviewers using the USDA's Automated Multiple Pass Method (AMPM). The first 24-hour recall is collected in-person during the Mobile Examination Center (MEC) exam, and the second is taken over-the-telephone three to ten days later (19). Proxy respondents report intake for children who are five years of age and younger, and proxy-assisted interviews are conducted with children six to eleven years of age.

Defining Eating Frequency

The AMPM uses probes to collect detailed information for each food and beverage consumed. Participants are asked to report the time each food and beverage is consumed and name each eating occasion from a pre-defined list. For purposes of this analysis, an eating occasion was defined as any distinct time when a respondent reported consuming at least one food or beverage item, *excluding water*. Eating frequency was defined as the number of daily eating occasions reported. Occasions labeled "breakfast, lunch, dinner, supper, brunch, snack, drink, desayano, almuerzo, comida, merienda, cena, entra comida, botana, bocadillo, tentempie" counted toward eating frequency, with the exception of water-only eating occasions. Further, any eating occasion labeled as an "extended consumption," for which consumption was initiated as part of a previously reported meal or snack, was combined into a single eating occasion with the original meal or snack. This was done by identifying all times at which two eating occasions were reported at the same time. For example, if a child reported an extended consumption and breakfast at 9AM, because he/she continued drinking a beverage beyond the end of breakfast, only one eating occasion contributed to his/her eating frequency. Eating frequency was determined for each participant for each 24-hour recall.

Statistical Analyses

To account for the complex, multistage, probability sampling methodology used to collect the 2005-2010 NHANES surveys, NCHS has developed sample weights which account for survey non-response, over-sampling, post-stratification, and sampling error for each two-year survey (18). In this analysis, three 2-year survey cycles have been combined; therefore, all weights were re-scaled so that they are representative of the population at the midpoint of the combined survey period (18). When dietary data from the in-person recall only were used, a rescaled dietary weight (WTDRD1) was used, while the rescaled MEC exam weight (MECWT) was used when dietary data from only the over-the-telephone recall were used (written communication with Joseph Goldman, Senior Statistician at NCHS). When data from both recalls were used together, a rescaled recall #2 weight (WTDR2D) was used.

To account for these rescaled sample weights as well as the correlation of sample persons, the survey procedures within Statistical Analysis Software (version 9.2, 2008, SAS Institute, Cary, NC) were used for all statistical analyses. Specifically, Proc SurveyMeans was used to generate descriptive statistics for eating occasions by day of the week. Within Proc SurveyReg, Student's t-test was used to compare number of eating occasions across days of the week as well as to estimate differences in reported number of eating occasions on week versus weekend days. Finally, to examine the agreement between reported number of eating occasions between the in-person and telephone recalls, a simple linear regression model was estimated. An alpha level of 0.05 was used to identify statistical significance. The Institutional Review Board of Tufts University approved this study as exempt.

RESULTS AND DISCUSSION

Due to the scheduling of the MEC exams, the in-person recall (recall 1) is disproportionately collected on a weekend day, which NCHS defines as Friday-Sunday, as shown in Table 1. NHANES attempts to collect the telephone recall (recall 2) on weekdays such that the majority of participants have one recall collected on a weekday and weekend day. Given these differences and the fact that eating behaviors differ on week versus weekend days in children (20), when exploring whether the two 24-hour recalls can be combined to estimate usual eating frequency, it is important to understand how the collection day of the week affects reported eating occasions.

When stratified by day of the week, the data indicate that the difference in eating frequency between days of the week for each recall is not statistically significant with the exception of Tuesdays for the in-person recall and Thursdays for the telephone recall (Table 1). Despite this finding, the reported mean number of eating occasions, or eating frequency, is significantly greater for the in-person recall as compared the telephone recall (recall 1: 5.16 (SE=0.03) eating occasions per day, recall 2: 4.70 (SE=0.03) eating occasions per day; t= 23.7; p<.0001). Specifically, eating frequency reported for the in-person recall is, on average, 0.5 occasions greater than reported for the telephone recall.

To further examine whether the differences in reported eating frequency reflect the fact that the in-person recall is disproportionately collected on weekend days (Friday-Sunday), two separate Student t-tests were performed. The results, shown in Table 2, suggest that there are no statistically significant differences in eating frequency between weekend and week days (recall 1: t=1.75, p=0.09; recall 2: t=1.13, p=0.26). When considered along with the data in Table 1, these analyses suggest that although the in-person recall is disproportionately collected on weekend days, this does not explain the observed differences in reported mean daily eating occasions between the two 24-hour recalls.

The standardized procedures for dietary data collection within NHANES, the AMPM, is designed to prevent any biases in way the 24-hour recall is collected (19); however, the fact that recall 1 is collected in-person, while recall 2 is collected by telephone may lead to subjects, particularly children, to alter their reporting behaviors. While we would anticipate some day-to-day variation, if the two recalls were interchangeable, we would not expect any systematic difference in the reported eating frequency between the two recalls. Such a systematic difference in reported eating frequency between the in-person and telephone recalls is apparent within the NHANES 2005-2010 dietary data.

To explore this systematic difference, we further examined the level of agreement between the reported eating frequencies for the two 24-hour recalls. The correlation between the reported eating frequencies across the two recalls is modest (0.43;

$p<0.0001$). Further, the results from a simple regression model, in which the dependent variable, recall difference (EODiff = eating frequency for recall 1 – eating frequency for recall 2), was regressed on the average number of eating occasions, or eating frequency, across the two recalls, suggest that for each additional average eating occasion reported, the difference in eating frequency reported between recalls 1 and 2 statistically significantly increases by 0.09 eating occasions/day ($\beta_1 = 0.09$, $p<0.001$). If there were consistent bias between the two 24-hour recalls, we would have expected a statistically non-significant effect estimate; however, given that this model yielded a statistically significant effect estimate suggests that the bias varies with eating frequency.

The findings that, on average, there is a 0.5 occasion difference in the number of eating occasions reported for the in-person as compared to over the phone recall, and that the estimates yielded by the two 24-hour recalls are not in agreement suggest that taking an average across them may not be the best approach to estimate usual eating frequency. Given that the observed differences are independent of the collection day of the week, it is possible that they are due to the differences in mode of collection used for the two 24-hour recalls. That is, during an in-person 24-hour recall, a research subject, particularly a child, may be more engaged in the process and better able to accurately recall each eating occasion. When the same interview is done by telephone, it is possible that there are more distractions and it is easier for a child to forget to report an entire occasion or more. It is also possible that the observed differences are due to the participants experience in already having completed a 24-hour recall. Children and proxies who have completed a previous 24-hour recall may be more likely to rush through the second telephone recall given their prior experience and knowledge of the process thereby omitting an eating occasion.

Previous research has examined the agreement between 24-hour recalls collected in-person and those collected by telephone (21-23). This body of research suggests that nutrient estimates from recalls taken using either methodology do not substantially differ; yet, these studies have only been done in women and have not considered differences in reported eating frequency across mode of administration. The current analysis is, to our knowledge, the first to examine differences in reported eating occasions between recalls collected using in-person versus those collected by telephone in children. An additional strength of this analysis is its large sample size using a diverse, nationally representative sample. Its primary limitation is the fact that there is no widely agreed upon definition for eating frequency or daily eating occasions.

CONCLUSIONS

The role of eating frequency, or the number of daily eating occasions, in childhood obesity is not well understood due to inconsistent findings in the scientific literature. Although some of these inconsistencies may be due to unclear definitions for eating frequency in general and for snacking in particular, they are also likely due the methodology used to measure diet in children (4). The results from this analysis suggest that eating frequency, as measured by non-consecutive repeat 24-hour diet recalls, significantly differ in children when the first recall is collected in-person and the second is collected by telephone. Specifically, dietary data from children ages 2-18 years who participated in 2005-2010 NHANES show that, on average, reported eating frequency for the in-person 24-hour recall is 0.5 occasions greater than that reported over the phone, independent of day of the week. This finding suggests that further research is needed to understand whether the differences in mode of collection are responsible for the observed differences in reported eating frequency across recalls in children. Additionally, these results call attention to the need for statistical methods which would allow researchers the ability to model usual eating frequency. However, even if statistical methodology to estimate usual eating frequency was well established, these reported biases may affect estimates of usual intake.

References

1. Popkin BM, Duffy KJ. Does hunger and satiety drive eating anymore? Increasing eating occasions and decreasing time between eating occasions in the United States. *Am J Clin Nutr*. 2010;**91**:1342-1347.

2. Piernas C, Popkin BM. Trends in snacking among U.S. children. *Health Aff*. 2010;**29**(3):398-404.

3. Briefel RR, Crepinsek MK, Cabili C, Wilson A, Gleason PM. School Food Environments and Practices Affect Dietary Behaviors of US Public School Children. *J Am Diet Assoc*. 2009;**109**(2, Supplement 1):S91-S107.

4. Meal or Eating Frequency and Overweight in Children [database on the Internet]. American Dietetic Association. 2011 [cited September 7, 2011].

5. Nicklas T, Yang S, Baranowksi T, Zakeri I, Berenson G. Eating patterns and obesity in children: the Bogalusa heart study. *Am J Prev Med*. 2003;**25**(1):9-16.

6. Thompson OM, Ballew C, Resnicow K, Gillespie C, Must A, Bandini L, et al. Dietary pattern as a predictor of change in BMI z-score among girls. *Int J Pediatr Obes*. 2006;**30**:176-182.

7. Vader A, Walters S, Harris T, Hoelscher D. Television viewing and snacking behaviors of fourth and eighth-grade schoolchildren in Texas. *Prev Chronic Dis*. 2009;**6**:A89.

8. Keast DR, Nicklas TA, O'Neil CE. Snacking is associated with reduced risk of overweight and reduced abdominal obesity in adolescents: National Health and Nutrition Examination Survey (NHANES) 1999-2004. *Am J Clin Nutr*. 2010;**92**(2):428-435.

9. Ritchie LD. Less frequent eating predicts greater BMI and waist circumference in female adolescents. *Am J Clin Nutr*. 2012;**95**(2):290-296.

10. Gregori D, Foltran F, Ghidina M, Berchialla P. Understanding the influence of the snack definition on the association between snacking and obesity: a review. *Int J Food Sci Nutr*. 2011;**62**(3):270-275.

11. Willett W. Nutritional Epidemiology. Second ed. New York: Oxford University Press; 1998.

12. Kipnis V. Macros for usual intake. In: Evans EW, editor. 2012.

13. Sebastian R, Cleveland L, Goldman J. Effect of snacking frequency on adolescents' dietary intakes and meeting national recommendations. *J Adol Health*. 2008;**42**:503-511.

14. Macdiarmid J, Loe J, Craig LCA, Masson LF, Holmes B, McNeill G. Meal and snacking patterns of school-aged children in Scotland. *Eur J Clin Nutr*. 2009;**63**(11):1297-1304.

15. Lioret S, Touvier M, Lafay L, Volatier JL, Maire B. Are eating occasions and their energy content related to child overweight and socioeconomic status? *Obesity* 2008;**16**:2518-2523.

16. Sebastian R, Goldman J, Wilkinson Enns C. Snacking patterns of U.S. adolescents: What We Eat In America, NHANES 2005-2006. Food Surveys Research Group Dietary Data Brief [Internet]. 2010 06/20/2012; (Brief No.2). Available from: http://ars.usda.gov/Services/docs.htm?docid=19476.

17. Dodd K, Guenther P, Freedman L, Subar A, Kipnis V, Midthune D, et al. Statistical methods for estimating usual intake of nutrients and foods: a review of the theory. *J Am Diet Assoc*. 2006;**106**:1640-1650.

18. Continuous NHANES Web Tutorial [database on the Internet]. Center for Disease Control and Prevention. 2009 [cited September 13, 2011]. Available from: http://www.cdc.gov/nchs/tutorials/Nhanes/index_continuous.htm.

19. National Center for Health Statistics. Key Concepts About NHANES Dietary Data Collection. 2010 [cited 2011 September 12]; Available from: http://www.cdc.gov/nchs/tutorials/dietary/SurveyOrientation/DietaryDataOverview/Info2.htm.

20. Rothausen BW, Matthiessen J, Hoppe C, Brockhoff PB, Andersen LF, Tetens I. Differences in Danish children's diet quality on weekdays v. weekend days. *Public Health Nutr*. 2012;**15**(09):1653-1660.

21. Yanek LR, Moy TF, RaqueÑO JV, Becker DM. Comparison of the Effectiveness of a Telephone 24-hour Dietary Recall Method vs an In-person Method among Urban African-American Women. *J Am Diet Assoc*. 2000;**100**(10):1172-1177.

22. Tran KM, Johnson RK, Soultanakis RP, Matthews DE. In-person vs Telephone-administered Multiple-pass 24-hour Recalls in Women: Validation with Doubly Labeled Water. *J Am Diet Assoc*. 2000;**100**(7):777-783.

23. Casey PH, Goolsby SLP, Lensing SY, Perloff BP, Bogle ML. The Use of Telephone Interview Methodology to Obtain 24-hour Dietary Recalls. *J Am Diet Assoc*. 1999;**99**(11):1406-1411.

Table 1. Reported eating frequency by 24-hour recall mode of administration and day of the week for children ages 2-18 years who participated in the National Health and Nutrition Survey (NHANES), 2005-2010

Day of the Week	In-person 24-hour Recall n (%)	Eating Occasions Mean (SE)*	Telephone 24-hour Recall n (%)	Eating Occasions Mean (SE)*
Sunday	1396 (16.6%)	5.12[a] (0.08)	1436 (17.2%)	4.63[a] (0.06)
Monday	709 (8.5%)	5.12[a] (0.07)	1860 (22.2%)	4.67[a] (0.04)
Tuesday	456 (5.5%)	5.22[a,b] (0.13)	1739 (20.8%)	4.59[a] (0.05)
Wednesday	625 (7.5%)	5.39[b] (0.09)	1892 (22.6%)	4.64[a] (0.05)
Thursday	613 (7.3%)	5.10[a] (0.09)	603 (7.2%)	4.88[b] (0.06)
Friday	2356 (28.2%)	5.09[a] (0.05)	644 (7.7%)	4.65[a] (0.08)
Saturday	2211 (26.4%)	5.08[a] (0.05)	188 (2.3%)	4.66[a,b] (0.10)

[a,b] Means (by recall) sharing superscripts in the same column do not differ significantly ($p<0.05$) – no adjustment has been made for multiple comparisons given multistage, complex sampling design used in NHANES

Table 2. Association between eating frequency and weekend day, defined as Friday-Sunday, in children ages 2-18 years who participated in the National Health and Nutrition Examination Survey (NHANES), 2005-2010[a]

24-hour Recall	t-statistic (p-value)	Weekend Eating Occasions Mean(SE)	Weekday Eating Occasions Mean (SE)
In-Person	1.75 (0.09)	5.09 (0.04)	5.21 (0.05)
Telephone	1.13 (0.26)	4.65 (0.05)	4.73 (0.04)

[a] Two separate Student t-tests performed via Proc SurveyReg to account for multistage, complex sampling design used in NHANES

Appendix C

Daily D Diet Sub-study Recruitment Materials

Daily D *Diet* Study

Is your child currently enrolled in the Tufts University Daily D Study?

Does he/she want to participate in a diet screening at today's study visit?

Participating students will meet with a Registered Dietitian **twice** to answer questions about their diet. One visit will take place before school and the other will be over the phone 3-10 days later.

Each student will receive an additional $25 Target gift card as a thank you for participation.

Please read the letter & consent form to learn more about this opportunity. If you have further questions, please call the study coordinator at 617-636-0903

Daily D *Diet* Study
The Gerald J. and Dorothy R. Friedman
School of Nutrition Science and Policy at Tufts University
Informed Consent
Jennifer Sacheck, PhD, Principal Investigator, Tufts University
E. Whitney Evans MS, RD, LDN, Friedman School, Tufts University

Purpose of Study
The Daily D Study is a 3-year community-based research project conducted by the Friedman School of Nutrition at Tufts University and supported by the National Institute of Health. The goal of the study is to examine the effect of vitamin D supplementation on vitamin D status and heart disease risk factors (such as cholesterol) in schoolchildren. In addition to vitamin D deficiency, overweight and obesity are very common in Massachusetts schoolchildren. Childhood overweight and obesity are preventable diseases with appropriate diet and exercise. The goal of this sub-study is to better understand the relationship between dietary patterns, television viewing, and childhood weight status. We plan to examine this relationship using dietary data and height, weight, and television viewing measurements collected within the Daily D Study.

Procedures to be Followed:
We are inviting all children who have enrolled in the Daily D Study to participate. This includes all children in grades 4-8 in your school who completed the first study visit in the fall of 2011. Participation in the Daily D Study asks that all children:

1. Arrive at school between 7AM and 8AM to a specified location within the school
2. Arrive after an overnight fast (not eaten any foods or beverages other than water that morning before arriving at school)
3. Have his/her height and weight measured
4. Have his/her skin color measured with an instrument that takes a picture of his/her arm
5. Complete dietary and physical activity questionnaires
6. Have his/her blood drawn (~2 teaspoons) one time by a trained phlebotomist for measurement of vitamin D and cardiometabolic risk markers

Children who participate in this sub-study will also be asked to complete two 24-hour diet recalls. This involves meeting with a dietitian and reporting every food and drink they had to eat over the prior 24-hour period. The first recall will be collected at school either on the day of the 3-month study visit for the Daily D Study OR within a few days of that visit. The second recall will take place over the phone within 3-21 days of the first recall. We will be calling your child by phone to take this second recall. If we are unable to reach your child by phone, we will make an effort to meet with him/her at the school within the same 3-21 day timeframe.

Confidentiality
Study day procedures will be performed within a private area of the school. All information collected about your child will be kept confidential. Once we receive your child's information, we will assign him/her a number code that will be used as his/her identification number throughout the study. All names and personal information will be kept in locked files at Tufts University, available only to the principal investigator and appropriate project staff. No one else will have access to your child's information. You or your child can decide not to participate at any time and you will no longer be contacted by the study investigator or support staff.

Risks

There are no additional risks associated with participation in the repeat 24-hour diet recalls.

Benefits
The benefit of participating in this study will be that its results may help us learn how to prevent and treat childhood overweight and obesity.

Costs
There is no cost to participate in this study.

Payment
Your child will receive a $25 payment in the form of a gift card for his/her participation in the sub-study after completing both 24-hour recalls. This is in addition to the $25 he/she will receive for completing the Vitamin D and Health Study protocol. The gift certificate will be mailed home or can be picked up after completion of the over-the-phone 24-hour diet recall.

Whom to Contact

Jennifer Sacheck, Ph.D.
Principal Investigator
Tufts University, Friedman School of Nutrition
150 Harrison Avenue
Boston, MA 02111
phone: 617-636-0903 fax: 617-636-3727
email: jennifer.sacheck@tufts.edu

Tufts Institutional Review Board
Tufts University, Medford, MA
(617) 627-3417
sber@tufts.edu

Rights
Taking part in this study is voluntary. You may choose for your child not to participate, or you may withdraw your child from the study at any time. You will be provided with your child's lipid results after the study, however, should your child's results indicate a risk for a health-related problem, we will inform you immediately. If at any time you decide to withdraw your child from participating in the study, his/her name will be removed from the database; however, any data previously collected will continue to be used. Withdrawal from the study will not affect your child's participation in any other activities at your child's school.

To allow your child to participate, please read both the parent and child statements and sign the **Informed Consent** on the next page. You can then return it to your child's school.

PARENT'S STATEMENT

- I have read this consent form and have been provided with contact information to ask questions. I understand that any questions that I might have will be answered verbally, or if I prefer, with a written statement.
- I understand that participation in this study is voluntary. I understand that I/my child may refuse to participate. I also understand that if I/my child want to discontinue participation, I/my child will be free to do so.

- I understand that my child will be participating in a 24-hour recall during the 3-month study visit for the Daily D Study, and that he/she will be called on the phone 3-21 days later to complete a second diet recall.
- If I have any questions concerning my child's rights as a research subject in this study, I may contact the Tufts University Human Investigation Review Committee at 617-627-3417.
- I have been fully informed of the above-described study with its risks and benefits, and I hereby consent to the procedures set forth above.
- I understand that as a participant in this study, my child's identity and data relating to this research study will be kept confidential, except as required by law.

Signature

To indicate your informed agreement, please read the following statement, answer the questions below, and sign your name.

The Daily D *Diet* Study, my child's part, and my part were defined and explained. I understand my role and my child's role as a participant. Any data regarding my identity or my child's identity will remain confidential. I understand that I am free to withdraw my consent and stop my child's participation at any time.

Child's Name (please print): ____

Parent/Guardian's Name (please print): __________________________________

*****Parent/Guardian's Signature:**____

*****Child's Signature:**____

Date:_____________________

Daily D *Diet* Study
The Gerald J. and Dorothy R. Friedman
School of Nutrition Science and Policy at Tufts University
Jennifer Sacheck, PhD, Principal Investigator, Tufts University
E. Whitney Evans MS, RD, LDN, Friedman School, Tufts University

We are doing a research study to figure out how what kids chose to eat affects their weight and health. You are being asked to join the **Daily D *Diet* Study** because you are already participating in the Daily D Study.

If you decide to participate in this additional part of the study, we will ask that you meet with a Nutritionist at the 3-month study visit to talk about your diet. You will also be asked to speak with the Nutritionist over the phone 3-10 days later to talk about your diet again. There are no right or wrong answers on to the questions the Nutritionist will ask you. We just want to know what kids eat and when.

Sometimes things happen in research studies that may make a kid feel badly. We don't think there is anything that will make you feel bad in this study, but if you do, you are free to tell us and we will listen. People can have good things happen to them in research studies. If you join this study, you may learn more about what you eat. You will also help us figure out how to help other kids eat healthfully.

Please talk with your parents before you decide if you would like to say "yes" and join this study. Even if your parents say "yes" you can still say "no" and not join. No one will be angry. Even if you say "yes" first, you may stop later. All you have to do is tell us you want to stop.

Before you say "yes" or "no", we will answer any questions you have. If you say "yes" and join the study, you can still ask questions. Just tell the researcher that you have a question. You or your parent can also contact Jennifer Sacheck, the leader of this study, at 617-636-0903.If you have any questions about anything that happens during the study, there is a special office at Tufts University called the Institutional Review Board that will listen to you and answer your questions. Your parents have the phone number for that office and can help you reach them. **Signing your name means that you agree to be in this study.**

____

Child's full name

______________________________________ ___________________

Child's signature **Date**

For office use only

I certify that I have explained fully to the above subject the nature and purpose, procedures, and the possible risks and benefits of this research study.

____ _________________

Signature of researcher or designate *Date*