UNDERSTANDING THE UNDERLYING SOCIAL, MATERNAL, AND ENVIRONMENTAL RISK FACTORS FOR THE DEVELOPMENT OF OVERWEIGHT AND OBESITY FROM BIRTH TO ADOLESCENCE

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UNDERSTANDING THE UNDERLYING SOCIAL, MATERNAL, AND ENVIRONMENTAL RISK FACTORS FOR THE DEVELOPMENT OF OVERWEIGHT AND OBESITY FROM BIRTH TO ADOLESCENCE

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Background

The relationship between changes in family socioeconomic status (SES) and the development of obesity in childhood is unknown. The purpose of this research was to investigate the relationship between growth and two measures of SES change in childhood: family income trajectory and early-life food insecurity, and whether SES modified the relationship between the school nutrition and physical activity (N&PA) environment and growth during middle school, 6th to 8th grade.

Methods

This longitudinal research employed a birth cohort (n=595) located in rural New York State, followed from birth to 15 years. Data were collected through an audit of medical records, mailed questionnaires, and an assessment of the middle school N&PA environments. Family income and body mass index (BMI) z-score trajectories were created using latent-class modeling techniques to group children based on similar trends across time. Linear mixed models were used to estimate rate change in BMI z-score.

Results

1. Children with poorer income trajectories were more likely to be in overweight and obese trajectories. Children who were persistently low-income were more likely to be in the overweight-stable BMI trajectory, and downwardly mobile children were more likely to be in the obese BMI trajectory.

2. The association between food insecurity and growth status varied across time. Food-insecure children had a lower estimated BMI z-score in early childhood compared to food-secure children, but their elevated rate of growth during childhood resulted in a higher estimated BMI z-score by the age of 15 compared to food-secure children.

3. The association between the school environment and change in BMI z-score depended on income trajectory. Specifically, reductions in BMI z-score were associated with better physical education and general physical activity promotion environments among adolescents with unstable and persistent low-income trajectories.

Conclusion

Low SES trajectories and food insecurity were positively associated with the development of overweight and obesity in complex ways across childhood. Depending on an adolescent's income trajectory, better middle school environments for physical activity were associated with decreased obesity risk.

BIOGRAPHICAL SKETCH

Margaret Mochon Demment was born and raised in Woodland, California. She was the salutatorian of Woodland High School Class of 2001. In 2005, she graduated *cum laude* from Williams College in Williamstown, Massachusetts in Biology, with a minor in Environmental Studies. Upon graduation she was awarded the Robert F. Rozenburg prize for outstanding scholarship, potential for solving local, national, or international environmental problems, and strong prospects for leadership in the environmental community. Margaret went on to be the logistics manager and researcher for a community-based conservation project in Iringa, Tanzania through the Wildlife Conservation Society. As she helped managed the research projects of others she began to realize that she had her own questions she wanted to explore and decided to apply to graduate school in nutrition. Margaret felt that nutrition was an important intersection between individual, community, and environmental health. In 2008, Margaret enrolled in the community nutrition Ph.D. program at Cornell University. While at Cornell, she was a teaching assistant for two semesters and was later granted a graduate fellowship from the USDA to prepare doctoral students to address the ecology of obesity. In 2010, Margaret received a dissertation award from Active Living Research, a national program of the Robert Wood Johnson Foundation to fund the school assessments of her research. Margaret completed her dissertation research under Dr. Christine Olson studying the underlying risk factors for the development of overweight and obesity in a rural birth-cohort from New York State. Upon completion of her Ph.D. she hopes to find ways to merge research and practice to affect change in communities that need it the most.

To my father for inspiring me to do good work,

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LIST OF ABBREVIATIONS

BEST	Bio-ecological systems theory
BMI	Body mass index
N&PA	Nutrition and physical activity
SES	Socioeconomic status
WFL	Weight-for-length
WHO	World Health Organziation

CHAPTER 1

Introduction

The desire to understand the complex relationship between underlying social inequalities and the development of overweight and obesity in childhood motivates this dissertation. This research employed longitudinal data from a rural New York State birth-cohort with growth data from birth to age 15. The 15 years of growth data provided an opportunity to move beyond traditional longitudinal outcomes, such as weight gain, and instead identify dynamic aspects of growth that put children at risk for overweight and obesity. Growth was captured in two different ways in this research. First, we created growth trajectories using latent-class modeling to group children together based on similar patterns of growth. This allowed comparison of children with normal-stable growth trajectories to children with rising or elevated growth trajectories. Second, we used linear mixed models to compare rates of growth between children with certain risk factors. These two measures of growth allowed examination of the macro trends—growth trajectories—and the micro trends—rate of growth—in the sample.

To examine how underlying social inequalities affected growth, we created a novel measure of socioeconomic status (SES): family income trajectory from birth to age 15. While there is ample evidence to suggest that poorer children do not perform as well on a wide variety of health measures, there has been inconclusive evidence to associate SES with childhood body mass index (BMI) (1,2). We employed income trajectory because we wanted to create a variable that simultaneously captured the duration, timing, and sequencing of low-income. We hypothesized that income trajectories elucidate the relationship between SES and BMI in children more clearly than traditional one-time measures of SES.

Using these longitudinal measures for both growth and income, we address key knowledge gaps in the development of overweight and obesity. The specific aims related to this research are:

1. **To identify family income trajectories that are associated with BMI z-score trajectories (2 to 15 years) in the context of early-life risk factors**. This aim provided a broad view of family income trajectories and early-life risk factors that were related to development of overweight and obesity.

> **Hypothesis**: Children with poorer income trajectories are more likely to become overweight or obese controlling for early-life risk factors that also contribute to increased risk of overweight and obesity.

2. **To determine if exposure to food insecurity early in life is associated with rates of growth in infancy (0 to 2 years) and/or childhood (2 to 15 years).** This aim examined the rates of growth in infancy and childhood to tease apart the more nuanced relationship between food insecurity and growth.

> **Hypothesis**: The timing of and changes in food insecurity status have different consequences for a child's growth.

3. To examine if family income trajectory modifies the relationship between the school nutrition and physical activity environment and BMI z-score during middle school (6^{th} to 8^{th} grade). The final aim applied the understanding of individual risk accumulated between birth and adolescence and then investigated if the middle school environment played a role in reversing or preventing overweight and obesity in adolescence.

Hypothesis: The school environment is associated with BMI among adolescents with poorer income trajectories more than it does those of higher income adolescents.

LITERATURE REVIEW

The remaining sections in this chapter provide the rationale and theoretical framework for each aim of this research as well as a summary of the existing literature in the field.

Aim 1: To identify family income trajectories that are associated with BMI z-score trajectories (2 to 15 years) in the context of early-life risk factors.

The Role of Socioeconomic status and health

Socioeconomic status (SES) is a multidimensional construct comprised of diverse socioeconomic factors, typically income, education, and occupation. SES can serve as an important predictor for a whole host of bio-psycho-social and environmental mechanisms that influence a child's risk of overweight or obesity. SES is widely used in models to help explain childhood overweight and obesity. Studies that lack appropriate measures of SES are often considered flawed due to confounding. However, social scientists still have not reached consensus on what SES precisely represents and how best to measure it (3,4). Despite its ambiguities, this relationship remains a topic of great interest to those who study health and childhood development. This interest is driven by an assumption that high SES families afford their children an array of services, goods, parental actions, and social connections that potentially contribute to the increased wellness of the children (5). By comparison, many low SES children lack access to those same resources and are thus at-risk for developmental problems (5).

A myriad of potential mechanisms have been proposed to link SES and childhood obesity, such as: food insecurity, parenting style, household stress, neighborhood characteristics, school characteristics, exposure to food advertising, fruit and vegetable consumption, fast-food consumption, opportunities for physical activity, sports participation, and time spent outdoors (6). The broad range of mechanisms through which SES could act suggest that simpler measures of SES may not fully capture the gravity of being low-income. To create a more complex measure of SES this research employed the life course perspective.

The life course perspective

It is hypothesized that the strength and nature of the relationship between SES and health may vary at different stages of the life course. The life course perspective suggests that personal development represents a combination of social, biological, and historical factors (7). A life course is a sequence of defined events and roles that the individual enacts over time (7). One feature of a life course is trajectories. Trajectories are stable patterns of behavior or health across time (8). Typically, trajectories in a person's life tend to develop together in a consistent way, as well as reinforce each other (9). Consequently, changes in one trajectory, such as SES, may lead to changes in other trajectories such as growth. In Aim 1, we investigate if trajectories in growth and family income develop together.

Cross-sectional trends in SES and childhood overweight and obesity

In the U.S., racial/ethnic and socioeconomic disparities in childhood obesity are well-documented (1,10–12). The extent to which social disparities in obesity and overweight prevalence have changed over time has received less attention. Wang and Zhang used NHANES data from 1971 to 2002 and found differences in the association between overweight and SES by race, sex, and age (1). They found an inverse association between low SES and overweight only existed in white girls compared to their high SES counterparts, while African American children with a high SES were at increased risk for overweight compared to their low SES counterparts. They also observed a weakening cross-sectional trend between socioeconomic disparities in overweight over time because overweight and obesity has increased in higher SES groups (1). Their studies provided important and new information about the demographic characteristics that modify the relationship between SES and growth but they used a single dimension of social status—family income measured at a single time point (13).

In a more recent analysis by Sing and colleagues (11) they examined cross-sectional trends using multiple measures of SES. They used 2003 and 2007 data from the National Survey of Children's Health and found that obesity prevalence has increased by 10% for all U.S. children, but increased by 23-33% for children of low-education, low-income, and higher unemployment households (11). By using multiple measures of social status the authors observed rising inequalities in U.S. children, not decreasing inequalities as previous studies have suggested. They attribute this to the broad range of social and economic factors that had not been considered in previous analyses. This suggests that how SES is measured has an impact on potential findings.

Longitudinal studies

While the understanding of trends in SES and childhood obesity has increased, few studies have examined within-person longitudinal effects. Longitudinal studies allow greater inference of causality and provide information about how changes in low-income affect growth. There are a handful of studies that have looked at the longitudinal relationship between SES and the development of obesity in children (14–16). All of these studies, however, looked at the change in weight status between adolescence and adulthood. While, understanding the link between childhood and adult obesity is critical, it is likely that SES plays a role in the development of obesity early in life and this potential relationship warrants examination.

Developmental trajectories

To capture the macro trends in growth, this research used growth trajectories. The benefit of using growth trajectories is that it allows for the identification of different growth patterns. These patterns could have important implications for the type and timing of interventions. To our knowledge, two other studies (17,18) have examined childhood BMI trajectories in association with early-life risk factors. Both studies found significant associations between maternal overweight and high-rising BMI trajectories. Both studies examined the association between SES measures and BMI trajectory, but neither found significant associations. The first study by Li and colleagues (17) used maternal education and family income at one time period to capture SES. They found that neither of these variables was significantly associated with the odds of BMI trajectory membership. The second study by Pryor and colleagues (18) used a dichotomous measure of low-income at one time period, maternal education, and family functioning. They did not find a significantly associated between any of their SES measures and the odds of BMI trajectory membership.

Aim 2: To determine if exposure to food insecurity early in life is associated with rates of growth in infancy (0 to 2 years) and/or childhood (2 to 15 years).

After examining growth trajectories and family income in Aim 1, we wanted to examine a specific aspect of being poor and in growth rate rather than growth trajectories. In Aim 2, the focus is the relationship between food insecurity status, early-life risk factors, and rate change in growth during infancy (0 to 2 years) and childhood (2 to 15 years). Given the few longitudinal studies that examine food insecurity and growth, this analysis expands the understanding of the co-occurrence of food insecurity and overweight and obesity in children. There are two sub-sections that provide the background for this aim: 1) potential mechanisms linking food insecurity and obesity and 2) a summary of the previous work in this area.

Food insecurity in the US

In the United States in 2011, more than one out of five children live in a household with food insecurity (19). Food *insecurity* is defined by an inability to consistently access nutritious and adequate amounts of food necessary for healthy life; while food *security* is defined by access by all people at all times to enough food for an active, healthy life (20). Food insecurity disproportionately impacts households with incomes below the poverty line (42.2%) and household with children that are headed by a single female (37.2%) or male adult (27.6%) (19).

Potential mechanism linking food insecurity and obesity

It has been proposed that food insecurity may lead to weight gain because the least expensive food options are typically high in calories and low in nutrients (21,22). Research suggests that high-calorie foods are easy to over-consume and promote weight gain if they are part of a regular diet (23,24). Households with limited resources tend to spend less on food overall and less, specifically, on healthy foods that are lower in energy and more costly (e.g., fruits and vegetables) (22). Dietary data have shown that children from low-income food insecure households consume fewer calories, carbohydrates and fruits, and have higher cholesterol values than their food secure, higher-income peers (25). In addition, food-insecure children consume fewer fruits, dark green vegetables, grains, yogurt, nuts, seeds, and dried beans and peas, but more sugar and eggs than children from food-secure households. These findings illustrate that the quality of children's diets differ as a function of their food security status.

While the quality of children's diets differs based on food security, the cascade of effects from that measure does not stop at dietary intake. Members of food-insecure households face high levels of stress due to the financial and emotional pressures of food insecurity. It has also been proposed that food insecurity effects growth indirectly through stress via two pathways. First, stress can act through biological pathways, increasing levels of cortisol, which causes metabolic abnormalities that can contribute to obesity (26). Second, stress may also contribute to poor eating habits and lower physical activity levels, which are both associated with overweight and obesity (27).

Cross-sectional associations between food insecurity and childhood obesity

The complex potential mechanisms by which food insecurity and obesity are related suggest that cross-sectional studies have important limitations. However, they do provide a snapshot of how food insecurity and obesity may be related. At least 20 cross-sectional studies (25,28–46) have examined whether a relationship exists between household food insecurity and growth among U.S. children and adolescents. The majority of the studies found no evidence of a direct relationship between household food insecurity and growth. Only 5 studies (34,37,41,44,46) found evidence to indicate that some groups of children living in food-insecure households are more likely to be overweight/obese, while 4 studies (28,29,31,42) found evidence that children living in food-insecure households are less likely to be overweight/obese. Taken together, the findings of the cross-sectional studies suggest the relationship between food insecurity and growth is inconsistent and may vary by population and/or age.

Longitudinal studies

Longitudinal data has clear analytical advantages over cross-sectional data. First, the temporal nature allows for measurement of change over time. Temporality insures that the outcome is associated with the initial exposure status and not due to reverse causality. In this case, reverse causality could be that larger kids may consume more food to meet their energy requirements, thus increasing the likelihood of their families being food insecure. Second, the investigation of within-person changes reduces the effects of unmeasured confounders. To examine the relationship between food insecurity and growth in children, longitudinal data provide the best design to establish that observed effects are causal and not due to reverse causality or confounding.

Only 5 longitudinal studies (39,47–50) have examined the relationship between household food insecurity and growth among US children since 2000 (51). The Early Childhood Longitudinal Study-Kindergarten cohort was used in 4 of these studies (39,47–49) to examine the relationship between food insecurity and growth in children from kindergarten to 3rd grade. Only one study (49) found evidence that girls in food-insecure households are more likely to be obese or experience greater gains in BMI over time compared to girls who are food secure. The remaining studies found no evidence of a direct relationship between household food insecurity and growth. Nor was evidence found indicating that children living in food-insecure households are less likely to be obese. The other longitudinal study by Bronte-Tinkew and colleagues (50) used the Early Childhood Longitudinal Study-Birth Cohort and found an indirect association between food insecurity and overweight at age 2, which was mediated by parenting and infant feeding practices.

Aim 3: To examine if family income trajectory modifies the relationship between the school nutrition and physical activity environment and BMI z-score during middle school (6th to 8th grade).

The first two sub-sections address the conceptual and theoretical framework for this aim. The following sub-sections provide the background for why this study focuses on: 1) adolescents; 2) middle school nutrition and physical activity (N&PA) policies and environments; 3) the role of SES; and 4) rural adolescents. The objectives of Aim 1 and 2 were to understand the development of overweight and obesity and identify children who are most at-risk. Aim 3 builds from the first two aims in an effort to examine whether a possible underlying influence of growth—family income trajectory can modify the relationship between growth and an environmental leverage point—middle school, at critical time point—adolescence.

Obesogenic Environments

There is growing evidence and consensus in the scientific community that obesogenic environments are a significant, if not primary, cause of increasing obesity rates (52). Obesogenic environments promote obesogenic behaviors such as unhealthy eating and limited physical activity. Therefore, environments and the policies that impact how environments are created or used are critical for reducing obesogenic behaviors. Schools are opportune settings for interventions to address obesity as children spend approximately half of their waking hours in school. Schools provide 1 to 2 meals daily, especially among low-income and food-insecure children, and often provide the only structured physical activity a child receives.

Despite the growing consensus that the environment influences nutrition and physical activity behavior, the science of measuring and evaluating this relationship is still in its infancy (53). Current methods for assessing the school environment are often conducted with a particular focus on one aspect of the environment, such as vending machine availability and content. In addition, previous studies on the school environment have focused heavily on self-reported data from students and administrators with no objective measures of the environment or input from key people who control selected aspects of the school environment. Several recently published reviews on the impact of the environment on childhood obesity revealed the following critical areas for future research: examining rural populations that vary in income, using longitudinal rather than cross-sectional data, and combining physical activity and nutrition variables (54–56).

Bio-Ecological Systems Theory

This aim utilizes the bio-ecological systems theory (BEST) (57), which highlights the need to consider contextual influences on childhood obesity. Biological, behavioral, and environmental components are intertwined in bio-ecological systems theory and none can be fully considered without understanding the systems in which they are embedded (58). There are three primary levels within bio-ecological systems theory, illustrated in **Figure 1.1**.

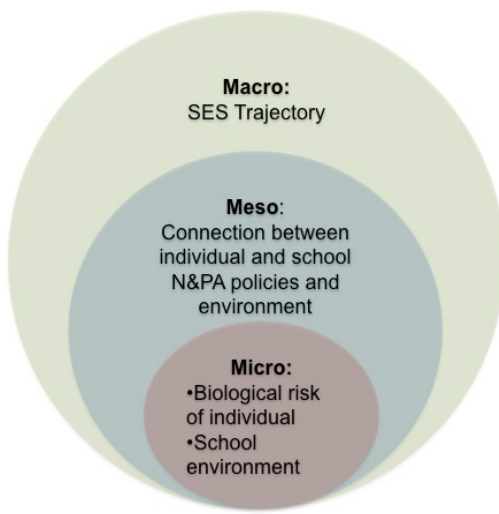


Figure 1.1. Aim 3 in the context of BEST

First, the micro level represents the biological risk of the individual and school environment. Second, the meso level refers to connections between contexts, for example, the interaction between the individual's biological risk and their school environment. Third, the macro level is comprised of the effects of culture, society, and economics that have a cascading influence throughout the interactions of all other layers. In our model we represent the macro level with family income trajectory, which seeks to capture this cascading influence of social and economic status of the adolescent. In this model, contributors of growth are considered holistically as integral parts of the ecological system.

Adolescence: a critical period

There are both biological and behavioral mechanisms that make adolescence a critical period for the development of obesity (59,60). Adolescence is the last of three critical stages for the development of childhood obesity (60). As children, especially girls, transition into adolescence they undergo hormonal and physical changes that put them at greater biological risk for obesity, including increased fat deposition (59). Adolescent BMI is a strong predictor of adult BMI, approximately 50 percent of overweight adolescents will become obese adults (61–64). Health related behaviors and attitudes that develop during adolescence continue into adulthood making this a critical stage for the development of lifelong patterns (65,66). Current studies show prevailing obesogenic behaviors in adolescents, such as the decline in physical activity, especially for females (67). Purchase and consumption of food while away from the home also increase during adolescence (68,69). While the home environment may be highly influential during early development this diminishes in adolescence, competing with external influences such as peer pressure and acceptance and conformity needs (68). Due to this biological and behavioral risk, adolescence offers a unique leverage point to positively influence the adoption of healthful eating and physical activity behaviors that could be sustained into adulthood.

Middle school nutrition and physical activity environment

Middle schools can play a critical role in impacting adolescent BMI trajectories, especially among rural adolescents. The middle school N&PA environment represent the connection between the adolescent and the school environment in the BEST conceptual model. Middle schools support the development of behaviors in adolescents that will carry on into adulthood and thus have the chance to play a critical role in adult obesity prevention. Adolescent physical activity declines rapidly from ages 9 to 15 (70), which provides the middle school environment an opportunity to maintain physical activity in adolescents. In a national survey only 7.9 percent of middle schools provided daily PE to students in 2006 (71). On the other side of the energy balance equation, the school policies and environments are recognized as having a powerful influence on students' eating behaviors (72,73). In a nationally-representative sample, findings suggest that the frequency of fruit and vegetable provisions, food availability in vending machines, other competitive food outlets, and start of school time are all policy avenues that may be used to effect student BMI and food consumption in adolescents (74). Interventions at the school level have impacted dietary intake and physical activity behaviors but few studies have measured the impact on BMI (75). This study addresses this gap by examining the association between the middle school N&PA environment and BMI during middle school.

Rural Overweight and Obesity

Rural children are less active and more at risk for overweight and obesity than their metropolitan counterparts (76–78). This relationship remains even after accounting for disparities in income and access to healthcare, suggesting that the rural environment may be more obesogenic. Children living in rural areas in the U.S. are about 25 percent more likely to be overweight and obese than their metropolitan counterparts (76). Rural children have the additional risk of increased poverty, no health insurance, no preventive care in the past year, and little physical activity (76). The popular image of the rural active lifestyle is no longer accurate; rural children are less active and have more screen time than there urban counterparts (79). Research from several studies in the U.S. and abroad show that the distance between home and school is the strongest influence on whether kids walk or bike to school (80). Therefore, rural environments may be more obesogenic because the very nature of being rural means that some students will travel great distances to arrive at school, often by bus, resulting in less physical activity built into a child's day. Rural populations also have less access to resources that could support healthy eating and physical activity. Schools serve as a central node in a rural adolescent's life and may be one of the few places policy or environmental interventions could impact adolescents outside of the home.

REFERENCES

1. Wang Y, Zhang Q. Are American children and adolescents of low socioeconomic status at increased risk of obesity? Changes in the association between overweight and family income between 1971 and 2002. Am. J. Clin. Nutr. 2006 Oct;84(4):707–16.

2. Chang VW, Lauderdale DS. Income disparities in body mass index and obesity in the United States, 1971-2002. Arch. Intern. Med. 2005 Oct 10;165(18):2122–8.

3. Liberatos P, Link BG, Kelsey JL. The measurement of social class in epidemiology. Epidemiologic Reviews. 1988 Jan 1;10(1):87 –121.

4. McLoyd VC. The impact of poverty and low socioeconomic status on the socioemotional functioning of African-American children and adolescents: Mediating effects.

5. Bradley RH, Corwyn RF. Socioeconomic status and child development. Annu. Rev. Psychol. 2002 Feb;53(1):371–99.

6. Yancey AK, Kumanyika SK. Bridging the Gap: understanding the structure of social inequities in childhood obesity. Am J Prev Med. 2007 Oct;33(4 Suppl):S172–174.

7. Giele JZ, Elder GH. Methods of life course research: qualitative and quantitative approaches. SAGE; 1998.

8. Wethington E. An Overview of the Life Course Perspective: Implications for Health and Nutrition. Journal of Nutrition Education and Behavior. 2005 May;37(3):115–20.

9. Damon W, Lerner RM. Handbook of Child Psychology: Theoretical models of human development. John Wiley and Sons; 2006.

10. National Center for Health Statistics. Health, United States, 2008 with Special Feature on the Health of Young Adults. Hyattsville, MD: US Department of Health and Human Services; 2009.

11. Singh GK, Siahpush M, Kogan MD. Rising social inequalities in US childhood obesity, 2003-2007. Ann Epidemiol. 2010 Jan;20(1):40–52.

12. Singh GK, Kogan MD, Van Dyck PC, Siahpush M. Racial/ethnic, socioeconomic, and behavioral determinants of childhood and adolescent obesity in the United States: analyzing independent and joint associations. Ann Epidemiol. 2008 Sep;18(9):682–95.

13. Weight Gain During Pregnancy: Reexamining the Guidelines [Internet]. [cited 2012 Jun 17]. Available from: http://www.nap.edu/openbook.php?record_id=12584&page=1

14. Wells NM, Evans GW, Beavis A, Ong AD. Early childhood poverty, cumulative risk exposure, and body mass index trajectories through young adulthood. Am J Public Health. 2010 Dec;100(12):2507–12.

15. Lee H, Harris KM, Gordon-Larsen P. Life Course Perspectives on the Links Between Poverty and Obesity During the Transition to Young Adulthood. Popul Res Policy Rev. 2009 Aug 1;28(4):505–32.

16. Scharoun-Lee M, Kaufman JS, Popkin BM, Gordon-Larsen P. Obesity, race/ethnicity and life course socioeconomic status across the transition from adolescence to adulthood. Journal of Epidemiology and Community Health. 2009 Feb 1;63(2):133 –139.

17. Li C, Goran MI, Kaur H, Nollen N, Ahluwalia JS. Developmental trajectories of overweight during childhood: role of early life factors. Obesity (Silver Spring). 2007 Mar;15(3):760–71.

18. Pryor LE, Tremblay RE, Boivin M, Touchette E, Dubois L, Genolini C, et al. Developmental trajectories of body mass index in early childhood and their risk factors: an 8-year longitudinal study. Arch Pediatr Adolesc Med. 2011 Oct;165(10):906–12.

19. Coleman-Jensen A, Nord M, Carlson S. Household food security in the United States in 2010. 2011 Sep p. 37. Report No.: ERR-125.

20. USDA Economic Research Service - Definitions of Food Security [Internet]. [cited 2012 Sep 28]. Available from: http://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx

21. Ludwig DS, Pollack HA. Obesity and the economy: from crisis to opportunity. JAMA. 2009 Feb 4;301(5):533–5.

22. Drewnowski A, Specter SE. Poverty and obesity: the role of energy density and energy costs. Am. J. Clin. Nutr. 2004 Jan;79(1):6–16.

23. Hartline-Grafton HL, Rose D, Johnson CC, Rice JC, Webber LS. Energy density of foods, but not beverages, is positively associated with body mass index in adult women. Eur J Clin Nutr. 2009 Dec;63(12):1411–8.

24. Rolls BJ. The relationship between dietary energy density and energy intake. Physiol. Behav. 2009 Jul 14;97(5):609–15.

25. Casey PH, Simpson PM, Gossett JM, Bogle ML, Champagne CM, Connell C, et al. The association of child and household food insecurity with childhood overweight status. Pediatrics. 2006 Nov;118(5):e1406–1413.

26. Pervanidou P, Chrousos GP. Metabolic consequences of stress during childhood and adolescence. Metab. Clin. Exp. 2012 May;61(5):611–9.

27. Jenkins SK, Rew L, Sternglanz RW. Eating behaviors among school-age children associated with perceptions of stress. Issues Compr Pediatr Nurs. 2005 Sep;28(3):175–91.

28. Buscemi J, Beech BM, Relyea G. Predictors of obesity in Latino children: acculturation as a moderator of the relationship between food insecurity and body mass index percentile. J Immigr Minor Health. 2011 Feb;13(1):149–54.

29. Matheson DM, Varady J, Varady A, Killen JD. Household food security and nutritional status of Hispanic children in the fifth grade. Am. J. Clin. Nutr. 2002 Jul;76(1):210–7.

30. Gundersen C, Lohman BJ, Garasky S, Stewart S, Eisenmann J. Food security, maternal stressors, and overweight among low-income US children: results from the National Health and Nutrition Examination Survey (1999-2002). Pediatrics. 2008 Sep;122(3):e529–540.

31. Borre K, Ertle L, Graff M. Working to eat: Vulnerability, food insecurity, and obesity among migrant and seasonal farmworker families. Am. J. Ind. Med. 2010 Apr;53(4):443–62.

32. Gundersen C, Garasky S, Lohman BJ. Food insecurity is not associated with childhood obesity as assessed using multiple measures of obesity. J. Nutr. 2009 Jun;139(6):1173–8.

33. Lohman BJ, Stewart S, Gundersen C, Garasky S, Eisenmann JC. Adolescent overweight and obesity: links to food insecurity and individual, maternal, and family stressors. J Adolesc Health. 2009 Sep;45(3):230–7.

34. Metallinos-Katsaras E, Sherry B, Kallio J. Food insecurity is associated with overweight in children younger than 5 years of age. J Am Diet Assoc. 2009 Oct;109(10):1790–4.

35. Feinberg E, Kavanagh PL, Young RL, Prudent N. Food insecurity and compensatory feeding practices among urban black families. Pediatrics. 2008 Oct;122(4):e854–860.

36. Gundersen C, Lohman BJ, Eisenmann JC, Garasky S, Stewart SD. Child-specific food insecurity and overweight are not associated in a sample of 10- to 15-year-old low-income youth. J. Nutr. 2008 Feb;138(2):371–8.

37. Smith C, Richards R. Dietary intake, overweight status, and perceptions of food insecurity among homeless Minnesotan youth. Am. J. Hum. Biol. 2008 Oct;20(5):550–63.

38. Martin KS, Ferris AM. Food insecurity and gender are risk factors for obesity. J Nutr Educ Behav. 2007 Feb;39(1):31–6.

39. Rose D, Bodor JN. Household Food Insecurity and Overweight Status in Young School Children: Results From the Early Childhood Longitudinal Study [Internet]. [cited 2012 Jul 22]. Available from: http://pediatrics.aappublications.org

40. Whitaker RC, Orzol SM. Obesity among US urban preschool children: relationships to race, ethnicity, and socioeconomic status. Arch Pediatr Adolesc Med. 2006 Jun;160(6):578–84.

41. Bhattacharya J, Currie J, Haider S. Poverty, food insecurity, and nutritional outcomes in children and adults. J Health Econ. 2004 Jul;23(4):839–62.

42. Jones SJ, Jahns L, Laraia BA, Haughton B. Lower risk of overweight in school-aged food insecure girls who participate in food assistance: results from the panel study

of income dynamics child development supplement. Arch Pediatr Adolesc Med. 2003 Aug;157(8):780–4.

43. Kaiser LL, Melgar-Quiñonez HR, Lamp CL, Johns MC, Sutherlin JM, Harwood JO. Food security and nutritional outcomes of preschool-age Mexican-American children. J Am Diet Assoc. 2002 Jul;102(7):924–9.

44. Alaimo K, Olson CM, Frongillo EA Jr. Low family income and food insufficiency in relation to overweight in US children: is there a paradox? Arch Pediatr Adolesc Med. 2001 Oct;155(10):1161–7.

45. Casey PH, Szeto K, Lensing S, Bogle M, Weber J. Children in food-insufficient, low-income families: prevalence, health, and nutrition status. Arch Pediatr Adolesc Med. 2001 Apr;155(4):508–14.

46. Widome R, Neumark-Sztainer D, Hannan PJ, Haines J, Story M. Eating when there is not enough to eat: eating behaviors and perceptions of food among food-insecure youths. Am J Public Health. 2009 May;99(5):822–8.

47. Bhargava A, Jolliffe D, Howard LL. Socio-economic, behavioural and environmental factors predicted body weights and household food insecurity scores in the Early Childhood Longitudinal Study-Kindergarten. Br. J. Nutr. 2008 Aug;100(2):438–44.

48. Winicki J, Jemison K. Food Insecurity and Hunger in the Kindergarten Classroom: Its Effect on Learning and Growth. Contemporary Economic Policy. 2003;21(2):145–57.

49. Jyoti DF, Frongillo EA, Jones SJ. Food Insecurity Affects School Children's Academic Performance, Weight Gain, and Social Skills. J. Nutr. 2005 Dec 1;135(12):2831–9.

50. Bronte-Tinkew J, Zaslow M, Capps R, Horowitz A, McNamara M. Food insecurity works through depression, parenting, and infant feeding to influence overweight and health in toddlers. J. Nutr. 2007 Sep;137(9):2160–5.

51. Larson NI, Story MT. Food Insecurity and Weight Status Among U.S. Children and Families: A Review of the Literature. American Journal of Preventive Medicine. 2011 Feb;40(2):166–73.

52. Hill JO, Peters JC, Catenacci VA, Wyatt HR. International strategies to address obesity. Obes Rev. 2008 Mar;9 Suppl 1:41–7.

53. Lytle LA. Measuring the Food Environment State of the Science. Am J Prev Med. 2009 Apr;36(4 Suppl):S134–S144.

54. Ferreira I, van der Horst K, Wendel-Vos W, Kremers S, van Lenthe FJ, Brug J. Environmental correlates of physical activity in youth – a review and update. Obesity Reviews. 2007 Mar;8(2):129–54.

55. Razani N, Tester J. Childhood Obesity and the Built Environment. Pediatric Annals. 2010 Mar;39(3):133.

56. Galvez MP, Pearl M, Yen IH. Childhood obesity and the built environment. Current Opinion in Pediatrics. 2010 Apr;22(2):202–7.

57. Bronfenbrenner U, Morris PA. The Bioecological Model of Human Development. In: Damon W, Lerner RM, editors. Handbook of Child Psychology. Hoboken, NJ, USA: John Wiley & Sons, Inc.; 2007.

58. Skelton JA, DeMattia L, Miller L, Olivier M. Obesity and Its Therapy: From Genes to Community Action. Pediatric Clinics of North America. 2006 Aug;53(4):777–94.

59. Dietz WH. Critical periods in childhood for the development of obesity. The American Journal of Clinical Nutrition. 1994 May;59(5):955.

60. Dietz WH. Overweight in childhood and adolescence. N. Engl. J. Med. 2004 Feb 26;350(9):855–7.

61. Gordon-Larsen P, The NS, Adair LS. Longitudinal trends in obesity in the US from adolescence to the third decade of life. Obesity (Silver Spring). 2010 Sep;18(9):1801–4.

62. Power C, Lake JK, Cole TJ. Measurement and long-term health risks of child and adolescent fatness. Int. J. Obes. Relat. Metab. Disord. 1997 Jul;21(7):507–26.

63. Serdula MK, Ivery D, Coates RJ, Freedman DS, Williamson DF, Byers T. Do obese children become obese adults? A review of the literature. Prev Med. 1993 Mar;22(2):167–77.

64. Srinivasan SR, Bao W, Wattigney WA, Berenson GS. Adolescent overweight is associated with adult overweight and related multiple cardiovascular risk factors: the Bogalusa Heart Study. Metab. Clin. Exp. 1996 Feb;45(2):235–40.

65. Neumark-Sztainer D, Story M, Perry C, Casey MA. Factors influencing food choices of adolescents: findings from focus-group discussions with adolescents. J Am Diet Assoc. 1999 Aug;99(8):929–37.

66. Story M, Neumark-Sztainer D, French S. Individual and Environmental Influences on Adolescent Eating Behaviors. Journal of the American Dietetic Association. 2002 Mar;102(3, Supplement 1):S40–S51.

67. US Department of Health and Human Services. Physical activity and health: a report of the surgeon gerneral. Atlanta, Ga: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion; 1996.

68. Brown K, McIlveen H, Strugnell C. Nutritional awareness and food preferences of young consumers. Nutrition & Food Science. 2000;30(5):230 – 235.

69. Turner JJ, Kelly J, McKenna K. Food for thought: parents' perspectives of child influence. Brit Food J. 2006;108(3):181–91.

70. Nader PR, Bradley RH, Houts RM, McRitchie SL, O'Brien M. Moderate-to-Vigorous Physical Activity From Ages 9 to 15 Years. JAMA: The Journal of the American Medical Association. 2008 Jul 16;300(3):295–305.

71. Lee SM, Burgeson CR, Fulton JE, Spain CG. Physical education and physical activity: results from the School Health Policies and Programs Study 2006. J Sch Health. 2007 Oct;77(8):435–63.

72. Centers for Disease Control and Prevention. Guidelines for school health programs to promote lifelong healthy eating. MMWR Morb Mortal Wkly Rep. 1996;45(RR-9):1–33.

73. Kubik MY, Lytle LA, Hannan PJ, Perry CL, Story M. The association of the school food environment with dietary behaviors of young adolescents. Am J Public Health. 2003 Jul;93(7):1168–73.

74. Terry-McElrath YM, O'Malley PM, Delva J, Johnston LD. The school food environment and student body mass index and food consumption: 2004 to 2007 national data. J Adolesc Health. 2009 Sep;45(3 Suppl):S45–56.

75. Jaime PC, Lock K. Do school based food and nutrition policies improve diet and reduce obesity? Preventive Medicine. 2009 Jan;48(1):45–53.

76. Lutfiyya MN, Lipsky MS, Wisdom-Behounek J, Inpanbutr-Martinkus M. Is rural residency a risk factor for overweight and obesity for U.S. children? Obesity (Silver Spring). 2007 Sep;15(9):2348–56.

77. Gauthier BM, Hickner JM, Noel MM. High prevalence of overweight children in Michigan primary care practices. An UPRNet study. Upper Peninsula Research Network. J Fam Pract. 2000 Jan;49(1):73–6.

78. Davis CL, Flickinger B, Moore D, Bassali R, Domel Baxter S, Yin Z. Prevalence of cardiovascular risk factors in schoolchildren in a rural Georgia community. Am. J. Med. Sci. 2005 Aug;330(2):53–9.

79. Joens-Matre RR, Welk GJ, Calabro MA, Russell DW, Nicklay E, Hensley LD. Rural–Urban Differences in Physical Activity, Physical Fitness, and Overweight Prevalence of Children. The Journal of Rural Health. 2008;24(1):49–54.

80. Cohen DA, Ashwood JS, Scott MM, Overton A, Evenson KR, Staten LK, et al. Public parks and physical activity among adolescent girls. Pediatrics. 2006 Nov;118(5):e1381–1389.

CHAPTER 2

General methods

The general methods for this research includes 4 subparts: 1) study design and sample; 2) data collection; 3) variables and measurement; and 4) analysis. The first section briefly outlines the study design and sample. The second section explains the collection of data. The third focuses on the study variables and how they were measured. Finally, the types of analyses used are described.

STUDY DESIGN

The research for this dissertation is an observational, epidemiological study with a cohort design. This research employed three sources of data. The first source was information gathered from mothers enrolled in the Bassett Mothers Health Project 1 (BMHP1) who gave birth to a child from June 1995 to July 1997. BMHP1 was a prospective cohort study designed to examine the biological, behavioral, psychological, and socio-demographic characteristics of women and the relationships of these characteristics to postpartum weight retention (1). Women were followed for a time period spanning from before the end of the second trimester of pregnancy until two years postpartum.

The second source of data was retrospective audits of the medical chart for each child, born to a mother from the BMHP1, through the Bassett Healthcare Network. The aim of the medical chart audits was to collect information on the health and growth of the children born to the mothers of BMHP1. The primary audit of medical charts occurred from July 2009 to June 2010.

The third source of data was a contemporary assessment of the middle school nutrition and physical activity (N&PA) environments. The assessment included four components: 1) principal questionnaire; 2) food service director questionnaire; 3) head PE teacher questionnaire and 4) researcher observation checklist. The aim of the school assessments was to distinguish school environments that promote healthy eating and physical activity from environments that do not.

Sample

The population-based birth cohort was comprised of 595 full-term, singlet births, delivered from June 1995 to July 1997. At the time of BMHP1 (1994-1999) the Bassett Health Network served 8 rural, central New York State counties. Bassett Hospital, where all deliveries took place, was the only hospital in the geographical area delivering babies, thus the children of this study represent a population-based birth cohort. This population-based sample was predominantly white (96%) with a high proportion born to families that were below 185% of the poverty line at the time of the birth (44%). **Table 2.1** presents the different samples used for each research aim.

Table 2.1. Differences in sample size by Aim

-

	Aim 1	Aim 2	Aim 3
Variable of interest ---------------->	Income trajectory	Food insecurity	School envi.
Sample	2 to 14 years	0 to 14 years	6^{th} to 8^{th} grade
Population-based	---------------595---------------		
With growth measurements	517	517	380
With school assessment	-	-	281
Complete-case (no missing data)	501	348*	253
Analysis sample (imputed)	517	517	280**

*Reduction in sample size in complete-case for Aim 1 vs. Aim 2 is due to the missing food insecurity data.

**Reduction in sample size for Aim 3 from all adolescents with growth measurements to analysis sample is due to the eligibility criteria for the school assessment

The analysis sample for both research Aim 1 and 2 was comprised of 517 (87%) children with at least one body mass index (BMI) z-score measurement after the age 2. The attrition from birth to 2 years was predominantly due to families moving out of the 8-county region served by the Bassett Healthcare Network. The baseline characteristics of the original population-based sample and the analysis sample are shown in **Table 2.2.** None of the variables of interest differ significantly between the samples and thus the analysis sample remains a reasonable one for exploring the hypotheses.

Table 2.2. Characteristics of population-based sample and analysis sample

	Population-based sample n=595		Analysis Sample n=517		
Income measure	%	N	%	N	p-value[a]
Low-income at birth					0.4954
Yes	44	257	43	220	
No	56	334	57	293	
Missing		4		4	
Early-life risk factors					
Maternal overweight/obesity					0.5717
Yes	50	295	49	254	
No	50	300	51	263	
Gestational weight gain					0.2798
Excessive	47	282	47	244	
Inadequate	18	106	17	88	
Within recommendations	35	207	36	185	
Smoking during pregnancy					0.8864
Yes	20	114	20	99	
No	80	477	80	414	
Missing		4		4	
Control Variables					
Multiparious					0.2302
Yes	41	243	42	216	
No	49	352	48	301	
Age category					0.1434
<25 years	26	153	27	140	
> 25 years <30 years	33	195	32	167	
> 30 years	41	247	41	210	
Birthweight					0.1718
1st quartile	26	157	25	128	
4th quartile	25	147	25	128	
2nd and 3rd quartile	49	291	50	261	
Sex					0.1167
Girl	47	278	48	248	
Boy	53	317	52	269	

*Chi-squared analysis p-value comparing analysis sample and those not included from the population sample.

In Aim 3, there were 2 levels for sampling: individual and school. At the individual level there were 380 adolescents who had a BMI measurement during their middle school grades, 6^{th} to 8^{th} grade. After accounting for attrition and the selection criteria for school assessment (at least 5 adolescents from the cohort attend the school), the analysis sample was comprised of 281 adolescents. The characteristics of the original population-based sample, the middle school sample, and the analysis sample are shown in **Table 2.3**.

Table 2.3. Characteristics of population, middle school, and analysis sample

	Population Sample		Middle School Sample			Analysis Sample		
	n=595		n=380			n=281		
Characteristic	No.	%	No.	%	p-value[a]	No.	%	p-value[b]
Maternal early pregnancy overweight/obese					**0.54**			**0.66**
Yes	295	50%	216	58%		161	57%	
No	300	50%	160	43%		120	43%	
Low-income at birth					**0.12**			**0.75**
Yes	258	43%	154	41%		120	43%	
No	337	57%	222	59%		161	57%	
Early-life growth trajectories					**<0.0001**			**<0.0001**
High rising	179	30%	139	37%		105	37%	
Low rising	293	49%	152	40%		105	37%	
Stable	123	21%	85	23%		71	25%	
Sex					**0.05**			**0.015**
Male	317	53%	189	50%		131	47%	
Female	278	47%	187	50%		150	53%	
Start of puberty								**0.63**
After middle school			66	17%		47	17%	
Before middle school			78	21%		61	22%	
During middle school			232	62%		173	61%	
Income trajectory								**0.18**
Persistent low-income			78	21%		62	22%	
Unstable low-income			69	18%		55	20%	
Never low-income			228	61%		162	58%	
Missing			5			2		
Current ADHD medication use								**0.59**
Yes			37	10%		29	10%	
No			339	90%		252	90%	

[a] Chi-squared analysis p-value comparing middle school cohort to those not included from the population sample.

[b] Chi-squared analysis p-value comparing analysis sample to those not included from the population sample, except the adolescent characteristics which were compared to those not included from the middle school cohort (puberty status, income trajectory, and current ADHD medication use).

Chi-square analyses were conducted to compare adolescents included in the analysis sample to those not included in order to identify any factors that might be different. There was a higher proportion of boys in the analysis sample compared to the loss to follow-up sample. There was also a smaller proportion of adolescents with low-rising growth trajectories (a control variable characterized by being small at birth and then rapid growth to age 2), in the analysis sample compared to the loss to follow-up sample. All other variables used in our analysis do not differ significantly across the samples and thus the analysis sample remains a reasonable one for exploring our hypotheses.

At the school-level, there were 51 schools in the region that the adolescents in the sample attended. We used the adolescents' medical records to determine which school they attended. There were 50 adolescents who did not have a school recorded with their measurements. For these adolescents, we used their most current address to determine which school district they resided in and the closest middle school to their home. All school districts had only one public middle school (2). It is possible that these children attended other schools, however, since these were rural areas with significant distances between schools, this is unlikely. Adolescents who were homeschooled were excluded from the middle school cohort (n=5). The range in number of students per school is presented in **Figure 2.1**.

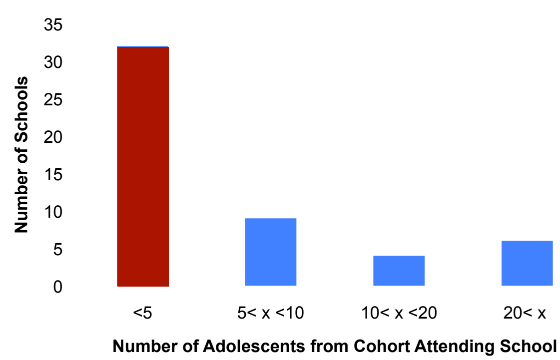


Figure 2.1. Number of Schools with Adolescents from Cohort Attending

The only exclusion criterion for the school assessments was having fewer than 5 students from the cohort attending the school. Schools that were excluded were more likely to be at the periphery of the area served by the Bassett Healthcare. For example, there were children who went for medical examinations at Bassett clinic in one county but attended middle school in another county not served by Bassett. After the exclusion criterion was applied there were 19 schools that were eligible for the school assessment.

DATA COLLECTION

Our research employed three sources of data: 1) Bassett Mothers Health Project 1; 2) audit of medical charts for children born to mother of BMHP1; and 3) middle school N&PA environment.

Data Source 1: Bassett Mothers Health Project 1

Setting

At the time of BMHP1 (1994-1999), the Bassett Healthcare Network served 8 counties in rural, central New York State. The 8 counties include: Otsego, Chenango, Delaware, Schoharie, Montgomery, Fulton, Herkimer, and Madison counties in New York State. All counties were rural, based on a population of less than 200,000, and with no town or city in any of the counties with a population of 20,000 people or more. Prenatal care was given at the Mary Imogene Bassett Hospital and 8 outreach clinics. All deliveries took place at the Mary Imogene Bassett Hospital in Cooperstown, NY.

Period of Recruitment

The study cohort was drawn from a pool of 1,519 women who had registered for obstetrical care at Bassett Healthcare from November 7, 1994 to November 15, 1996.

Eligibility Criteria

Women who met the following criteria were eligible for recruitment into the BHMP: 1) aged 18 years or older at the time of delivery; 2) entered prenatal care at or before 28 weeks of gestation; 3) planned to deliver in the Bassett Healthcare Network; 4) planned to carry the pregnancy to term; 5) planned to keep the baby; 6) did not have a mental or psychiatric condition that could preclude giving informed consent and completing questionnaires; and 7) did not have medical conditions prior to pregnancy which could influence weight loss or gain. These conditions included diabetes, gastrointestinal problems and hypertension with medications. Of the 1,519 women recruited into the study, 1,090 were eligible by these criteria. Of the 429 women found ineligible for the study the two main reasons for ineligibility were medical and psychiatric condition influence weight and spontaneous abortion. **Figure 2.2** presents the flowchart for participation in the BMHP1 project.

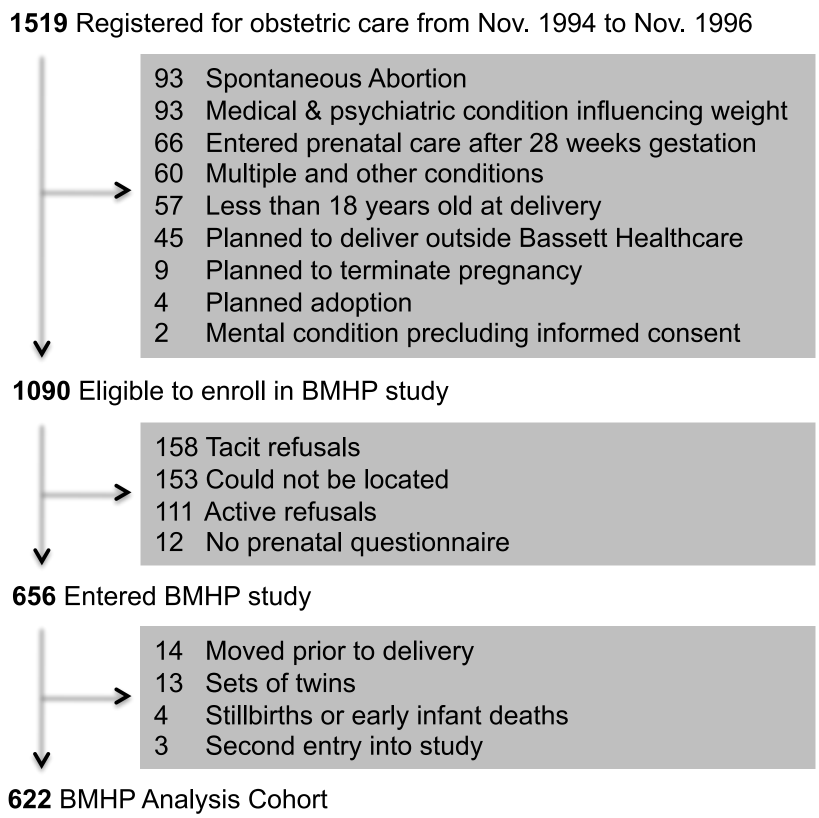


Figure 2.2. Flowchart of participation for BMHP1

Follow-up

Information regarding height, weight, age, education, food insecurity status and parity were recorded in the medical chart and was extracted from the chart shortly after delivery. A mailed twelve-page prenatal questionnaire asked women about their current body size, attitudes about weight, eating patterns, physical activity, past pregnancies, patterns of previous weight gain and/or loss, supportive relationships, feelings about motherhood, employment, and household characteristics. The questionnaire was completed by 3.5% of the sample in the first trimester, 68% in the second trimester, and 28.5% in the third trimester; the results did not differ by trimester.[3]

Follow-up data for the study were collected through mailed questionnaires and phone interviews at six weeks postpartum, six months postpartum, one year postpartum, and two years postpartum. These questionnaires focused on aspects of mother and infant health, including: infant feeding practices, food insecurity, maternal employment, and smoking. In addition to self-reported data from questionnaires, BMHP1 study researchers directly measured maternal weight at one year postpartum and two year postpartum.

Data Source 2: Medical Chart Audits

Setting

The Bassett Healthcare Network has expanded significantly since the beginning of BMHP1. The number of rural health clinics increased from 8 to 26 in the 8-county area. In addition there are now 18 school-based health centers that provide free healthcare to any child attending the school.

The children's growth measurements and other important individual covariates such as insurance codes, school attended, illnesses that might pertain to growth and development, and medication use, were obtained through an audit of their pediatric medical records through Bassett Healthcare from June 2009 to July 2010 by two graduate students, Stacy Carling and myself, hereafter the auditing team.

Audit Form Development

The forms used for the medical chart audit were developed by the auditing team, with the aim of capturing the growth, general health, and changes in income from birth to present. There are two forms, primary and visit, which were developed in Microsoft

Access 2003 (see **Appendix A** for a copy of forms and **Appendix B** for list of variables and their sources in medical chart). One primary form was filled out for each child whose records were audited (n=595) and one visit form was filled out for each child medical visit that yielded information about both weight and height or a change in address or health insurance (n=8173).

The primary form was designed to record data that did not change over time, including: date of last visit within the Bassett Healthcare Network, current or most recent address, data on birth, gender, race/ethnicity, birth weight, birth length, academic, emotional or behavioral problems, household environment and family structure, history of illness and medication use, and stated date of menstruation for girls.

The visit form was designed to record measurements over time for each child. For each measured height and weight, change in address, or change in medical record, a new visit form was completed for that child. Each visit form included the date of measurement, whether the visit was a well-visit, and the location (clinic site) of a visit. When available, information about insurance type (Medicaid, Child Health Plus, HMO/PPO/Private, Self-pay), address, current school, blood pressure, and Tanner staging was recorded. In the event that a visit in the medical record indicated a change in address or insurance type, a visit form was filled out even if there were no measured weights and heights associated with the particular visit.

The forms were first shared with the Olson Research Group for general feedback and were revised based on their suggestions. The forms were then shared with our PI at Bassett Healthcare, Dr. Chris Kjolhede. Dr. Kjolhede is a practicing pediatrician at Bassett Healthcare, directs the school based healthcare clinics, and has been involved in previous medical chart audits for Cornell University research. He provided important information on reliable sources of information within the medical records and where to look for certain types of information. The auditing team's forms were revised again on the basis of his suggestions.

Reliability

The auditing team began the auditing process by doing several charts together to minimize variation in auditing technique and interpretation of information. We devised an auditing strategy to include a blueprint for the location of certain information retrieved within the medical record. The auditing team worked in the same room for two weeks, continuing to discuss any ambiguities or questions to insure we were recording information in a similar manner. The auditing process continued until January 2010 with each of us often working alone or at separate clinics. We did have periodic trips to Cooperstown together that provided a periodic reliability check about what data we were collecting and how we were entering data. Regular meetings were held to discuss our progress, issues that arose, their solution, and future goals. In addition, bi-monthly progress reports were written and shared with Dr. Christine Olson and Dr. Chris Kjolhede.

Data were checked at multiple time points for missing information and suspected inaccuracies. Variables of particular interest were medical record numbers, birth weight, race/ethnicity, dates, and height and weight variables and units. Some missing variables were due to healthcare professionals failing to record the information, inaccessibility of a child's early record, or a record being simply missing or lost. Height and weight were rechecked based on measures flagged as "biologically impossible" based on World Health Organization 2007 growth standards. These and other data questions were addressed in a re-auditing process in May 2010. Medical charts were checked to insure accurate data collection. Some of these were errors in data entry, however, others reflect true recorded values and were included in the analysis. Those flagged variables that the auditing team were unable to check were excluded from the dataset.

Medical Chart Mediums

The medical chart for each child was often in multiple media: (1) microfilm, (2) paper, (3) archival electronic record, (4) school-based health centers and (5) current electronic record. First, paper charts that were no longer active were converted to microfilm in the mid-1990s. In our cohort the most common scenario for this conversion was a child who was born at Mary Imogene Bassett Hospital but received care at a satellite clinic. The microfilm chart usually contained data on the child's birth and potentially their early well visits (depending on the length of time they were seen at Mary Imogene Bassett Hospital). Second, paper charts were the major source of data for our cohort. Most clinics were using paper charts until 2007 and most of these charts had not been converted to electronic formats. Third, some paper charts that were inactive or became too big to keep on file were scanned and converted to an archival electronic record and were available through the electronic record database. Fourth, the school-based health centers provide a copy of the record of care in the child's medical record (either paper or electronic). Finally, all clinic sites are now using electronic medical records and this system contains the most recent information on care provided.

Chart Locations

Many children also had medical charts located at satellite clinics. Using the electronic database at Mary Imogene Bassett Hospital, we catalogued the various media and locations of each child's chart. Starting in 1999, the electronic database stored the satellite clinic associated with each visit. For each child we cataloged every satellite clinic at which they were seen and checked each clinic for a medical record.

Complications

There were four complications in obtaining complete medical records for each of the 595 children in the original cohort, shown in **Figure 2.3**. First, before 1999 the Bassett database only stored the date of the visit and not where the visit occurred. Therefore we have no record of where a child was seen before 1999. This led to incomplete audits for children who were seen at satellite clinics before 1999 and either left the system before 1999 or changed clinics before 1999. For these children we know they were seen within the Bassett Network but were not able to collect complete data on all of their visits. There are 46 of these records, of which 30 had no BMI measurements. Second, there were also three clinics, Stamford, Dash/Delhi, and Walton, where the paper charts were stored and were inaccessible to the auditing team. However, we still had access to the microfilm and electronic records for these children. Combined, the clinics had 11 charts that we were unable to audit, of which, 3 had no BMI measurements. Third, there were 42 children for whom we have no recorded BMI measurements. These children may have left the system before measurements could be recorded or had no visits where heights or weights were recorded. Finally, three children were excluded from our cohort for being severely ill with the following conditions: congenital heart disease, CHARGE (a chromosomal disorder that causes severe physical and medical development problems), and spastic diplegic cerebral palsy. The decision to exclude these individuals was derived from their abnormal growth and medical care treatments,

treatments that would likely affect their BMI and nutrition behaviors. After exclusion of these complications, this left 517 children who had BMI measurements.

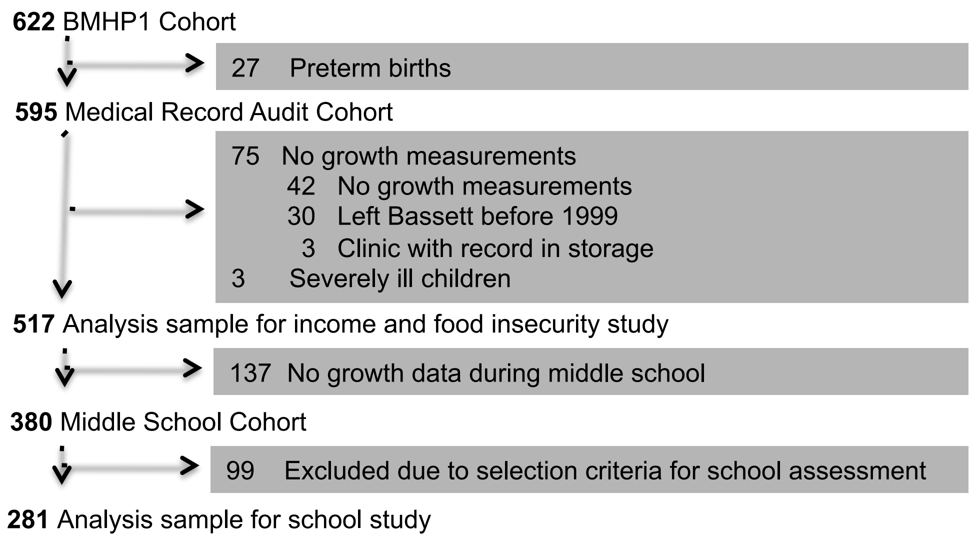


Figure 2.3 Flowchart for birth cohort

Limitations of Medical Chart Data

There are important limitations to these measurements that should be noted. Medical record data is subject to information bias. The data collected only reflects what doctors and nurses chose to write down in the records and may be an incomplete picture of the adolescent's life. Variables such as marital status of parents are especially vulnerable to this information bias. However, many of the variables were prompted in questionnaires during well visits (e.g. "Were there any major changes since your child's last visit?" With a list of variables for the parent to check: divorce, move, death in family, etc.). It is also important to note that information bias from medical records skews the results toward the null hypothesis. For example, it compares adolescents from a divorced family (in medical record), against adolescents that are comprised of a mixture of divorced and married families (no mention in medical record), making any biased findings conservative.

Final audit and data checking

A final audit of the medical charts was done in August 2011 to capture the youngest kids who turned 15 that year. All BMI z-score values were graphically represented for each adolescent and checked visually for abnormalities. Any abnormalities were flagged (n=20) and checked in the medical records for accuracy. Any abnormalities that could not be checked in the medical charts through the central Bassett location were excluded from analysis (n=1).

Data Source 3: School Assessment

The goal of the middle school N&PA environment assessment tool was to distinguish school environments that promote healthy eating and physical activity from environments that do not. The creation of the school assessment tool and the data collection consisted of 3 steps: 1) a literature review to see if the new tool was needed; 2) creation of the assessment tool based on our conceptual framework; and 3) collection of data.

Literature review

A literature review was conducted to: 1) determine the current consensus about what makes a health-promoting school; 2) identify strengths and limitations of existing measures; and 3) assess whether the proposed scale is actually needed. **Appendix C** catalogues instruments that have been developed to examine the school environment's relationship to nutrition and/or physical activity and what psychometric standards, if any, were used.

The literature review illustrated several limitations of the previous instruments and studies. First, there were few instruments or studies that used psychometric standards to test reliability and validity. Second, most studies focused on one aspect of the environment (e.g. vending machines or à la cart lunch options), rather than a comprehensive analysis of the N&PA environment. Third, most instruments used self-administered questionnaires completed by administrators or students, which could lead to a less objective characterization of the environment. All of these limitations are not present in each instrument but at least one is present in each, suggesting that in order to obtain a comprehensive analysis of the middle school N&PA environment a new tool was warranted.

These limitations in the assessment tool were addressed in 4 ways: 1) assessing both N&PA environments; 2) relying on multiple sources of data: administrators, public data, and researcher assessment; 3) using psychometric standards in developing the tool to inform changes and also assessing the reliability and validity of the tool after the data is collected; and finally, 4) dissecting the environment into 6 issue-specific scores to capture the multiple dimensions of the environment.

Creation of Assessment Tool

To better understand the relationship between environment and health-promoting behaviors we split the environment into concrete elements that were amenable to measurement. First, we distinguished the six issue-specific aspects of the environment that we wished to capture: 1) school meal quality and availability; 2) food fundraising policies; 3) general healthy eating promotion; 4) quality of physical education; 5) sport offerings and participation; and 6) general physical activity promotion. Then we employed the ANGELO framework[4] and divided each issues-specific aspect of the environment into four types: physical, economic, political, and socio-cultural (see **Appendix D**).

Along with the literature review, I visited two non-study middle schools to observe the school environment and talk with the principals, PE teachers, kitchen staff, and students about what they believe impacts students' eating and physical activity. These informal meetings were informative in the creation of the "item pool." Following the recommendations of Clark *et al.*[5] in "Constructing Validity: Basic Issues in Objective Scale Development," the creation of an item pool will be broader and more comprehensive than our own theoretical view of what makes a health promoting school. The logic underlying this principle is that it is better to capture too much initially than to miss a critical aspect of the school environment, since subsequent psychometric analyses can identify weak, unrelated items that can be dropped from the emerging scale.

Following the creation of the item pool, appropriate questions where drawn from existing tools and questions drafted for items with no current corresponding questions. The tool drew most heavily from the School Health Policies and Programs Study questionnaire (3) conducted by the CDC and the Eat Well Be Active questionnaire that was conceived from the ANGELO framework (4).

A draft of the tool was shared with Dr. Nancy Wells, Dr. Christine Olson, the Olson research group and presented at the Active Living Conference (5) to determine face validity. The tool was then tested on two additional non-study middle schools that were similar in demographics as the schools in the BMHP1 region. The tool was further revised based on this feedback. The most significant changes occurred within the principal survey to shorten and condense questions to reduce the respondent burden. The finalized tool was comprised of three surveys and one researcher observation (**Appendix E**). The tool was submitted to the Cornell IRB and approved March 23, 2011 (Protocol #1006001481).

Assessment Data Collection

All 19 schools were contacted first via email. This email outlined the purpose of the study and the time required to participate. Schools that did not respond were then contacted via phone until the principal was reached. All 19 schools participated in some aspect of the study. However, only 17 schools (89%) have complete data from all three respondents: principal, food service director, and PE teacher. The school assessments were conducted from June to August 2011.

VARIABLES AND MEASUREMENTS

The variables and measurements section of this chapter is divided into four sections describing how we measured: 1) growth; 2) family income trajectory; 3) early-life risk factors; and 4) the middle school N&PA environment.

Growth: weight-for-length z-scores, BMI z-scores, and trajectories

Measured heights and weights for each child were obtained through the medical chart audits and used to derive body mass index (BMI) z-scores and weight-for-length (WFL) z-scores, using the World Health Organization 2007 growth standards (6). The measurements were opportunistically captured when a child went to a clinic served by the Bassett Healthcare Network. The frequency of BMI z-score measurements was dictated largely by the regularly scheduled well-exam visits but the timing was different for each child. The average number of BMI z-score measurements per child in the sample was 16 (8 SD, 1 to 41 range).

We categorized growth in two ways: 1) trajectories which categorized growth using maximum-likelihood longitudinal latent-class modeling techniques; and 2) the rate of growth using linear mixed models. **Table 2.4** outlines the different measurement for each measure of growth.

Table 2.4. Measurements for growth used in analyses

Variable	Source	Measurement
Linear mixed modeling of WFL z-score and BMI z-score	Medical Records	WFL and BMI were calculated based on the heights and weights recorded in the medical records. WHO 2007 growth standards were used to calculate z-scores. All z-score values were graphically represented for each child and checked visually for abnormalities. Any abnormalities were flagged and checked in the medical records for accuracy.
Trajectories of WFL z-score and BMI z-score	PROC TRAJ	Group-based trajectories for WFL z-score from 0 to 2 years and BMI z-score 2 to 15 years were identified using maximum likelihood latent-class models in PROC TRAJ (7–10). The optimal number of trajectories were selected using the Bayesian Information Criterion (BIC) score and with the interest of parsimony (8,10). BIC does not always clearly indentify a preferred number of groups. The objective of the model selection was not the maximization of BIC, rather it was to summarize the distinctive features of the data in as parsimonious a fashion as possible (8,10). The two main outputs from the trajectory models are the shape of each group's trajectory and the probabilities of group membership. The program used the latter to classify individuals into trajectory groups (10).

Trajectory analysis

The next two sections briefly describe the 4-step process for how we chose the trajectories for BMI z-score and WFL z-score trajectories. First, the distribution of measures was assessed to insure there were enough observations to warrant a trajectory. There are currently no recommendations for required number of observations for trajectory analysis, however, we were mainly concerned with a majority of children having at least every 5 years. Second, models with different numbers of groups were run, which allowed us to compare change in BICs. Third, the number of trajectories was chosen to summarize the distinct features of the data in as parsimonious a fashion as possible. Finally, the exclusion of children with only a few measures would likely bias the results. Therefore, we ran chi-square analysis to compare the trajectory membership from the complete-case versus partial-case children to see if any significant differences were present.

BMI z-score trajectory, 2 to 15 years

There were 517 children with BMI z-score measurements from the original cohort. There were 321 (62%) children with BMI z-score measurements every 5 years. However, at least 75% of the analysis sample has BMI z-score measures during each 5 year time period (82%, 79% and 77%, respectively). **Table 2.5** presents the comparison of models predicting BMI z-score membership based on the number of groups defined with their corresponding change in BIC values.

Table 2.5. BMI z-score trajectory models by number of groups

Number of Groups	BIC	Null Model	2*ΔBIC	Evidence Against Null Model
4	-4893.39			
5	-4728.32	4	330.14	Strong
6	-4615.95	5	224.74	Strong
7	-4514.4	6	203.1	Strong
8	-4476.76	7	75.28	Strong
9	-4438.9	8	75.72	Strong
10	-4414.84	9	48.12	Strong
11	-4396.35	10	36.98	Some
12	-4396.53	11	-0.36	None

While the model with 10 groups is the best choice based on the statistical selection criteria (change in BIC), the 6-group model conceptually makes the most sense. The 6-group model defines groups both stable and rising at various starting points presented in **Figure 2.4.**

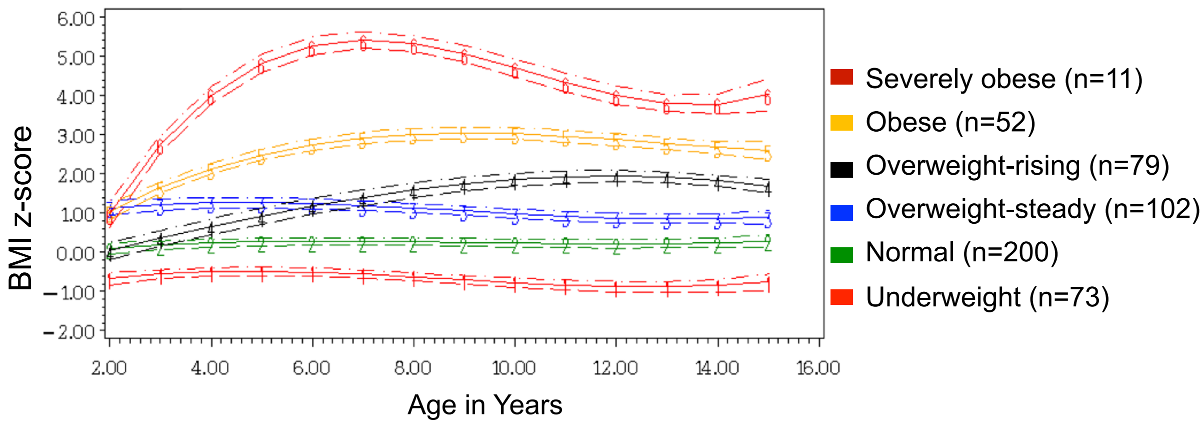


Figure 2.4. BMI z-score trajectories from 2 to 15 years

The objective of Aim 1 was to understand the development of overweight and obesity in childhood, therefore the separation of normal and underweight children is not necessary and they are combined into one group, not overweight. The sample size of the severely obese trajectory (n=11) was prohibitive to further analysis so they were combined with the obese trajectory. The four distinct groups that defined BMI z-score trajectory are presented in **Table 2.6**.

Table 2.6. Group membership by BMI z-score trajectory

Group	Number of children (%)	Former groups	General Trajectory
1	273 (53)	1 and 2	Not overweight
2	102 (20)	3	Overweight-stable
3	79 (15)	4	Become-overweight
4	63 (12)	5 and 6	Obese

To determine if the frequency of the measures would bias the results we ran a complete-case model and a partial-case model. The complete case model used only children with at least one measure every 5 years. The partial-case model used any child with measures regardless of the frequency. One benefit of latent-class modeling is that it uses all available data to estimate the likelihood of trajectory membership. The complete-case model for BMI z-score trajectory had a higher proportion of obese, 14% v. 12%, and become-overweight children, 20% v. 15%, when compared to the partial-case model (p=0.04). Therefore, it is likely that the findings are conservative and the inclusion of all children with BMI z-score data reduces potential bias.

WFL z-score trajectory, from 0 to 2 years

Of the population-based sample 592 had WFL z-score measurements. There were 291 children (48%) that had WFL z-score measures every six months. There was at least 65% of the analysis sample has WFL z-score measures during any given time period (93%, 84%, 79%, and 65%, respectively). **Table 2.7** presents the comparison of models predicting WFL z-score membership based on the number of groups defined with their corresponding change in BIC values.

Table 2.7. WFL z-score trajectory models by number of groups

Number of Groups	BIC	Null Model	2*ΔBIC	Evidence Against Null Model
3	-4429.21			
4	-4362.09	3	134.24	Strong
5	-4325.27	4	73.64	Strong
6	-4289.3	5	71.94	Strong
7	-4276.18	6	26.24	Some
8	-4272.6	7	7.16	Some
9	-4272.11	8	0.98	None

While, the change in BIC supports up to 6-groups, the 5-group model created the more conceptually sound groupings, shown in **Figure 2.5.**

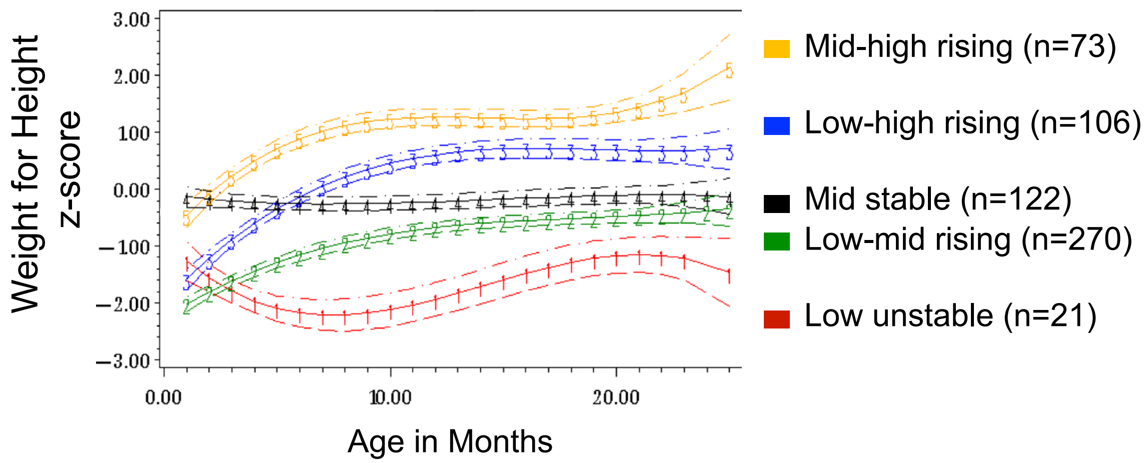


Figure 2.5. WFL z-score trajectories from 0 to 24 months

The objective of making this variable was to characterize atypical growth patterns that may lead to the development of overweight and obesity in childhood. We chose to combine mid-stable and low-unstable children into one stable group. We also chose to combine the mid-high and low-high rising groups into one high-rising group. **Table 2.8** presents the 3-groups used to characterize early-life growth.

Table 2.8. Group membership by WFL z-score trajectory

Group	Number of children (%)	Groups	General Trajectory
1	143 (24)	1 and 4	Stable
2	270 (46)	2	Low-rising
3	179 (30)	3 and 5	High-rising

To determine if the frequency of the measures would bias the results we ran a complete-case model and a partial-case model. The complete case model used only children with at least one measure every 6 months. The partial-case model used any child with measures regardless of the frequency. The complete-case and partial case models for WFL z-score trajectory had no significant differences between trajectory memberships.

Summary of growth variables used in different aims

We used the different measures of growth depending on the objectives of the study. **Table 2.9** outlines the different measures of growth used for each aim.

Table 2.9. Measures of growth used in the aims of the research

	Aim 1	**Aim 2**	**Aim 3**
Variable of interest ------------>	Income trajectory	Food insecurity	School envi.
Growth time period	2 to 15 years	0 to 15 years	6^{th} to 8^{th} grade
Early-life growth , 0 to 2 years	WFL z-score trajectories	WFL z-scores using linear mixed modeling	WFL z-score trajectories
Later-life growth, 2 to 15 years	BMI z-score trajectories	BMI z-scores using linear mixed modeling	BMI z-score using linear mixed modeling

Family income trajectory

Family income trajectory was the independent variable of interest for Aim 1 and an important covariate in Aims 2 and 3. We used maximum-likelihood longitudinal latent-class modeling techniques to classify children based on their family's movement in and out of low-income through childhood. This group-based modeling strategy determines the probability of children's low-income over time and simultaneously considered timing, duration, and sequencing of being low-income. **Table 2.10** presents the measurement of family income trajectory.

Table 2.10. Measurement of family income trajectory

Variable	Source	Measurement
Family income trajectory	Medical Records	Family income trajectory is based on insurance codes recorded at the time of the medical visit. A child is classified low-income if their insurance was listed as Medicaid or Child Health Plus, which requires families to be below 185% of the poverty line. Anecdotal evidence suggested that even if families had private insurance through a job, if they qualified for Child Health Plus they preferred to use it because there was not a co-pay. Group-based trajectories for income from 0 to 15 years were identified using maximum likelihood latent-class models in PROC TRAJ (7–10).

We followed the same 4-step process for the family income trajectory analysis as for the growth trajectories: 1) check the distribution of measures; 2) examine the number of groups per model based on BIC; 3) select the number of trajectories based on distinct features; and 4) compare of complete-case vs. partial-case trajectory membership.

There were 508 children with income measurements and 296 with income measurements every 5 years. At least 70% of the analysis sample had income measures during any given five-year periods (93%, 72% and 74%, respectively). This is a reasonable proportion to justify the creation of income trajectories across childhood. **Table 2.11** presents the comparison of models predicting income trajectory membership based on the number of groups defined with their corresponding change in BIC values.

Table 2.11. Income trajectory models by group numbers

Number of Groups	BIC	Null Model	2*ΔBIC	Evidence Against Null Model
3	-1347.4			
4	-1307.2	3	80.4	Strong
5	-1291.1	4	32.2	Strong
6	-1296.2	5	-10.2	None

While the model with 5 groups is the best choice based on the statistical selection criteria, change in BIC, the 4-group model defines four distinct groups with sufficient sample size for further analysis. **Figure 2.6** illustrates the four income trajectory groups.

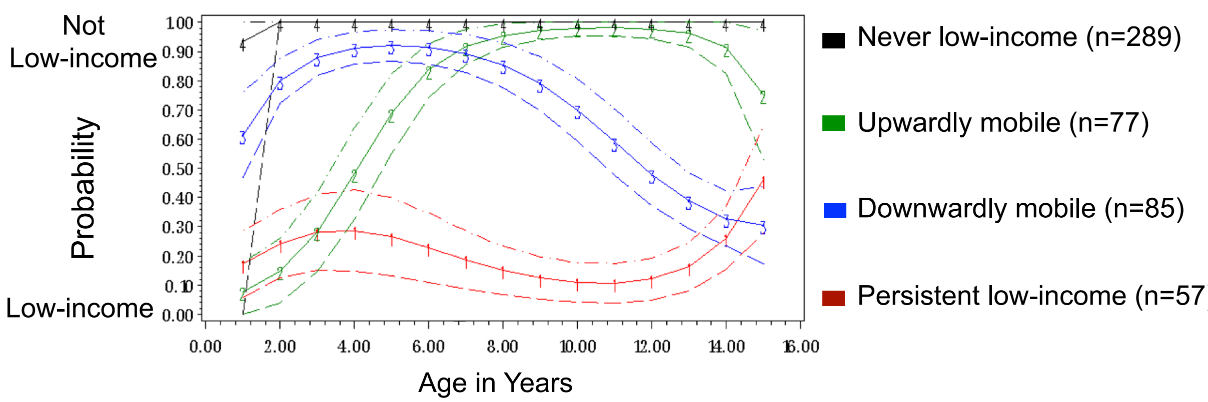


Figure 2.6. Income trajectories from 0 to 15 years

To determine if the frequency of the measures would bias the results we ran a complete-case model and a partial-case model. The complete case model used only children with at least one measure every 3 years. Income trajectory membership was not statistically different for the complete-case and partial-case models.

Other measures of income

Aim 1 examined the association between a multidimensional income trajectory and BMI z-score trajectory. **Table 2.12** presents other income variables created to see what differences, if any, would arise when compared to income trajectories.

Table 2.12. Other measures of low-income

Other variables of Low-income	Source	No. of children classified as low-income
Low-income at birth	PCAP (medical records)	214
Low-income at adolescence	4-group trajectories	142
Ever low-income	4-group trajectories	219

Early-life risk factors

Early-life risk factors were used in all of analyses, either as potential confounders or variables of interest. **Table 2.13** presents the early-life risk factors and their measurement.

Table 2.13. Measurement of early-life risk factors

Variable	Source	Measurement
Food insecurity	BMPH1	Food insecurity was captured at two time periods: before birth and at 2 years of age.
Early pregnancy BMI	BMPH1	Maternal overweight/obesity was classified using the Institute of Medicine BMI cutoff of $\geq$ 25 (11). Maternal overweight/obesity is a dichotomous variable (yes/no).
Gestational weight gain	BMPH1	Detailed gestational weight gain methods are described elsewhere (12). Briefly, the amount of weight gain was determined by subtracting the first measured weight in the first trimester of pregnancy from the weight at the last prenatal care visit, which was generally within one week of delivery. We used the Institute of Medicine's BMI categories and gestational weight gain guidelines to determine gestational weight gain category (11). Gestational weight gain is a categorical variable with three groups: excessive; inadequate; and adequate.
Smoking during pregnancy	BMPH1	Pregnancy questionnaire completed by mother.
Breastfeeding duration	BMHP1	Questionnaires completed by mothers at 6 weeks, 6 months, and 1 year.

Other variables used as potential confounders

Other potential confounding variables used in the analyses are presented in **Table 2.14.**

Table 2.14. Measurement of other potential confounding variables

Variable	Source	Measurement
Maternal education	BMPH1	We classified mother based on their education attainment: 1) high school or less; 2) some college or technical school; and 3) college or more.
Age of mother at delivery	BMPH1	Age was classified into 3 groups: 1) 18 to <25 year; 2) 25 to <29 years; and 3) $\geq$ 29 years.
Marital status	BMHP1	Marital status was classified based on if the mother was single/divorced or married at the time of delivery.
Multiparous	BMHP1	A mother was classified as being multiparous if she had previously delivered a live birth.

Child characteristics

We used gender, start of puberty, and medication use as control variables in the analyses. **Table 2.15** presents the measurement of each child characteristic.

Table 2.15. Measurement of child characteristics

Variable	Source	Measurement
Gender	BMHP1	Children were categorized based on the sex at birth.
Start of puberty	Medical Chart Audits	At most doctors visits when heights and weight were recorded the physician also assigned a Tanner score. The Tanner score is a gestalt of penis and scrotal changes and pubic hair distribution in males, and breast development and pubic hair distribution in females (13). For each male adolescent, Tanner scores (1 – 5) were evaluated and classified based if their Tanner score of 3 occurred: after, during, or before/early middle school. Female adolescents were classified based on their start of menses: after, during, or before/early middle school. In the sample menses data was missing for 28% of the females. In these cases, we used their Tanner scores with the classification as for males.
ADHD medication use	Medical Chart Audits	If an adolescent was currently using medication they were classified as on ADHD medications.
Antidepressant medication use	Medical Chart Audits	If an adolescent was currently using medication they were classified as on antidepressant medications.

Start of puberty

The only measure that captured puberty status was a tanner stage score. As described by Dr. Kjolhede, the tanner score is usually, "a gestalt of penis and scrotal changes and public hair distribution in males, and breast development and pubic hair distribution in females" (13). Each child had multiple tanner scores that corresponded with the date of their doctor visit. We choose to categorize the peak of puberty in adolescence by when a tanner score of 3 was achieved for boys or when menses started for girls.

In this sample, the boys and girls were categorized into the following 3 groups: started puberty before middle school (boys, 20% and girls, 21%); during middle school (boys, 55% and girls, 64%); and after middle school (boys, 25% and girls, 16%).

Middle School Nutrition and Physical Activity Environment

The tool was designed to focus on six issue-specific aspects of the environment: school meal quality and availability, food fundraising policies, general healthy eating promotion, quality of physical education, sport offerings and participation, and general physical activity promotion. The assessment of each school generated 301 items. Items from the assessment were excluded from the score creation if there was: little variation (72 variables); missing for more than 25% of the schools (4 variables); and condensed into one variable, for example the number of activities available for PE (25 variables). After exclusion, there were 200 variables remaining to create environment scores. All the variables within an issue-specific aspect of the environment were summed to create the issue-specific score, with higher scores indicating a healthier school environment. **Table 2.16** presents the dimensions of each score and the procedure for score creation.

Table 2.16. Measurement of the school N&PA environment

Variable	# of items in score	Source (dimensions captured)	Measurement
School meal quality and availability	106	Number of meals offered, types of foods offered, quality of facilities used to prepare and serve foods, who makes decisions about what food is offered, facilitators and barriers to providing healthier options, and the general attitudes and beliefs regarding the role of the food service at the school	Each question or observation was coded to capture if the environmental characteristic, policy or action was health promoting. A 1 or 0 was assigned to each dichotomous variable (yes or no). For answers that were not dichotomous, the distribution of answers was examined and coded based on being above or below the median. All the socio-cultural environment questions were originally answered based on a five-point scale (e.g., strongly agree, agree, neutral, disagree, strongly disagree), and these questions were summarized to a three-point scale based on the distribution of answers with an attempt to create a normal distribution.
Food fundraising policies	15	Frequency of fundraising involving food, rules regulating the placement and nutritional content of food, and role of fundraising in schools to support school activities	
General healthy eating promotion	13	Advertising for food/drinks, vending machines (placement, use of funds, rules of use), practices to improve healthy eating, and attitudes and beliefs of teachers and staff regarding healthy food promotion	
Quality of physical education	21	Facilities for PE, number of teachers, number and type of activities, perceived limitations, quantity of time spent being physical active during PE, and facilitators and barriers to improving PE	
Sports offerings and participation	6	Facilities for sports/clubs, number of coaches, availability of late bus, cost of sports teams/clubs, incentives for coaches, % participation by sex, and priority of sports/clubs within the school	
General physical activity promotion	39	Barriers to active transport to school, use of physical activity as punishment, use of facilities outside of sports/PE, and attitudes and beliefs regarding the role of physical activity in school	

School-level potential confounding variables

Other school level variables used to account for confounding factors that may influence the school environment were also used in analysis for Aim 3. **Table 2.17** outlines the variables and their measurement.

Table 2.17. Measurement of school-level potential confounding variables

Variable	Source	Measurement
School size	NY State Dept of Education	Obtained the enrollment number of the adolescent's school.
School's SES	NY State Dept of Education	Obtained the percentage of children eligible for free or reduced meal plans.
Rurality	NY State Dept of Education	Obtained how densely populated the area around the school is. Define by following National Center for Educational Statistics codes (14): 31 - Town, Fringe: Territory inside an urban cluster that is less than or equal to 10 miles from an urbanized area. 32 - Town, Distant: Territory inside an urban cluster that is more than 10 miles and less than or equal to 35 miles from an urbanized area. 33 - Town, Remote: Territory inside an urban cluster that is more than 35 miles from an urbanized area. 41 - Rural, Fringe: Census-defined rural territory that is less than or equal to 5 miles from an urbanized area, as well as rural territory that is less than or equal to 2.5 miles from an urban cluster. 42 - Rural, Distant: Census-defined rural territory that is more than 5 miles but less than or equal to 25 miles from an urbanized area, as well as rural territory that is more than 2.5 miles but less than or equal to 10 miles from an urban cluster. 43 - Rural, Remote: Census-defined rural territory that is more than 25 miles from an urbanized area and is also more than 10 miles from an urban cluster.
School type	NY State Dept of Education	Obtained grade levels of schools.

ANALYSIS

The analysis section of this chapter is divided into 3 sections that outline the statistical analyses used in each research aim. **Table 2.18** briefly summarizes the predictors, growth measures, and type of analysis used for each aim of the research.

Table 2.18. Summary of analyses by aim

Aim	Predictors	Growth measure	Type of analysis
Aim 1	Income trajectory and early-life risk factors	BMI z-score trajectory	Multinomial logistic regression
Aim 2	Food insecurity and early-life risk factors	WFL z-score (0 to 2 years) BMI z-score (2 to 15 years)	Linear mixed model
Aim3	School environment, income trajectory, and early-life risk factors	BMI z-score (6th to 8th grade)	Linear mixed model

AIM 1: Family income trajectory, early-life risk factors and BMI z-score trajectory

Multivariate multinomial logistic regression models were developed to estimate the odds of BMI z-score trajectory membership based on family income trajectory and early-life risk factors. Multinomial logistic regression generalizes logistic regression by allowing more than two discrete outcomes. The probabilities of the different possible outcomes of BMI z-score trajectory were modeled based on family income trajectory and early-life risk factors.

Preparation of data

All bivariate relationships between BMI z-score trajectory, family income trajectory, and potential early-life risk factors were examined using Chi-square analysis. All two-way interactions were assessed and included in the model if the p-value associated with the factor is <0.20. A p-value of <0.20 was selected due to the exploratory nature of much of the analysis. However, only variables with a p-value <0.05 were considered significant in the results.

Model building and hypothesis testing

All early-life risk factors were included in the initial model. Backward elimination was used to remove variables one at a time until each variable retained in the model had a p-value < 0.20. Significant variables had 95% confidence intervals that did not cross 1.

AIM 2: Food insecurity and rate change BMI z-score

Linear mixed models were used to assess the association between food insecurity paths and change in BMI z-score from 2 to 15 years. Linear mixed modeling is a type of hierarchical model that extends the linear regression model to longitudinal data. It includes fixed effects (i.e. population), random effects (i.e. individual) for a continuous outcome (e.g. BMI z-score), and a stochastic process to account for natural variation in BMI and the variation in time between the measurements.

Preparation of Data

Before modeling began, all variables were examined to insure satisfaction of regression assumptions. Growth measurements were examined for normality and were appropriately distributed without need of transformation. Outliers were assessed and were included in the model after accounting for medication use. All variables were assessed for collinearity, which left unaddressed could lead to unstable standard errors. All two-way interactions were assessed and included in the model if the p-value associated with the factor is <0.20. A p-value of <0.20 was selected due to the exploratory nature of much of the analysis. However, only variables with a p-value <0.05 were considered significant in the results.

Use of Random Effects

Random effects were used to model between-subject variation and the correlation induced by this variation. There are two forms of linear mixed models: 1) random intercept models, which account for individuals having different baseline measurements (e.g. not all children had the same BMI at the start of the study) and 2) random intercept and slope models, which accounts for individuals having different slopes (e.g. not all children had the same BMI trajectories). We tested which random effects model to use by plotting individuals' BMI over time. We found a fan-like pattern in slopes, which suggests a random intercept and slope model should be used and was justified in the analysis for this research.

Model

For simplicity, the model only includes the variables of interest for hypothesis testing, though the actual models included the covariates stated in the measurement methods. **Equation 1** describes the simplest within-person model, specifying that BMI for person *i* at age *j* is a function of the child's mean BMI and a random residual component.

$$BMI_{ij} = B_{oj} + \varepsilon_{ij} \quad \textbf{(Equation 1)}$$

Table 2.19 presents the variables used and interpretations.

Table 2.19. Model variables and inferences

Variable	What it represents	Inference
BMI_{ij}	BMI measurement for the subject *i* at age *j*	Outcome
B_{oj}	Fixed Effect: Cohort Intercept	Starting BMI for cohort
$B_1 Age_{ij}$	Fixed Effect: Cohort Slope	Average change in BMI associated with one unit increase in age
$B_{FI} FI_i$	Fixed Effect: Food insecurity path	Average change in BMI associated with SES Food insecurity path *i*
$B_{FI*Age} Age_{ij}*FI_i$	Fixed Effect: Food insecurity path over time	Average change in BMI associated with Food insecurity path *i* and one unit increase in age
b_{i0}	Random Effect: Variation in individual intercept	The deviation of intercept of subject *i* from the cohort intercept B_0
$b_{i1} Age_{ij}$	Random Effect: Variation in individual slope	The deviation of slope of subject i from the cohort slope B_1 ($B_1 + b_{i1}$ is the slope for subject *i*)
$U_i(Age_{ij})$	Stochastic Process	Natural variation in BMI
ε_{ij}	Residual Error	Measurement Error

This unconditional means model fits only an overall mean and the variance around the mean across all persons and measurement occasions.[18] The unconditional model provided a benchmark of within-person variance that was used to judge successive models.[19] The next step was to include time in the model. **Equation 2** is the basic fixed effects model where B_{oj} represents subject *i*'s predicted average BMI at the start of the study; and B_1 is the linear coefficient or the rate of change (slope) for subject i.

$$BMI_{ij} = B_{oj} + \mathbf{B_1 Age_{ij}} + \varepsilon_{ij} \quad \textbf{(Equation 2)}$$

Equation 2 was expanded further to include random effects. A stochastic process was also included to account for the natural fluctuation in BMI of an individual and the covariance matrix was structured to account for the unequal time periods between measurements, shown in **Equation 3**.

$$BMI_{ij} = B_{oj} + B_1 Age_{ij} + \mathbf{b_{i0} + b_{i1} Age_{ij}} + U_i(Age_{ij}) + \varepsilon_{ij} \quad \textbf{(Equation 3)}$$

Here the subject *i*'s slope is now explained by two variables the B_1 and b_{i1} (the population slope and subject *i*'s deviation from that slope). From here, hypothesis testing began.

Hypothesis Testing

The relationship between food insecurity path and BMI over time was examined, keeping WFL and BMI z-score as a continuous time-varying variable and food insecurity path as a categorical variable. To test this we created an interaction term between age and food insecurity path, shown in **Equation 4**.

$$BMI_{ij} = B_{oj} + B_1 Age_{ij} + B_{FI} FI_i + \mathbf{B_{FI*Age} Age_{ij} * FI_i} + b_{i0} + b_{i1} Age_{ij} + U_i(Age_{ij}) + \varepsilon_{ij} \quad \textbf{(Equation 4)}$$

From this model we compared the standard covariance parameters to examine how much variation in BMI is explained by adding this interaction into the model. For food insecurity path, each model was run four times with each food insecurity path serving as the reference group. This allowed us to test differences in growth not just between food-insecure children and food-secure children but to examine differences across all food insecurity paths. The parameter estimates using food-secure children as the reference are presented in the tables but alphabetical letters note significant differences between each food insecurity path. For example, if stay and become food insecure are different from food secure but not different from each other they would be labeled as such: stay food insecure "a"; become food insecure "a"; and food secure "b."

Other interaction terms between potential risk factors and time were also explored. Three-way interactions between food insecurity path and time and the following variables were also examined: stress, family income trajectory, and sex. We used backward elimination and removed non-significant variables one at a time until each variable retained in the model had a type-3 fixed effect p-value < 0.20.

AIM 3: School environment, family income trajectory, and BMI z-score during middle school

For Aim 3, school-level variables were added to the linear mixed model estimating changes in BMI z-score during middle school. The school-level is represented by the subscript k. By including the school in the model as a random effect, $b_k School_k(kid\_id)$, this accounted for the additional component of variance anticipated when a cluster sampling design is employed and observations from subjects are likely to be correlated. **Equation 5** shows the interaction term used to evaluate the association between the rate change (slope) in BMI z-score during middle school differed and issue-specific score by income trajectory.

$$BMI_{ijk} = B_{oj} + B_1 Age_{ij} + B_{envi} Envi_k + B_{SES} Income_i + B_{SES*age} Age_{ij} {*} Income_i + \mathbf{B_{envi*income} Envi_k Income_i} + b_{i0} + b_{i1} Age_{ij} + b_k School_k(kid\_id) + U_i(Age_{ij}) + \varepsilon_{ij} \quad \textbf{(Equation 5)}$$

Missing data and multiple imputations

Multiple imputations are recommended to reduce the potential for biased results based on excluding subjects with missing data (15). Currently, there is no consensus on the propriety of imputing the dependent variable (16). We chose to follow the recommendations of Allison (17) and not impute the BMI z-score trajectory in this analysis because there was minimal missing data in the independent variables of interest and no strongly correlated auxiliary predictors. In cases such as ours, multiple imputations for the dependent variable do not improve upon complete case analysis (17). However, for the small amount of missing data on early-life risk factors and controls we imputed these variables using fully conditional specification imputation method for categorical and discrete variables in PROC MI (18), which resulted in five imputed datasets. We did include the dependent variable in imputation models as recommended and later excluded those that did not have growth measurements (17). We used PROC LOGISTIC or PROC MIXED for the multivariate analysis and PROC MIANALYZE to pool the outcomes from the five datasets. All analyses described were performed with both the imputed datasets and a sample comprised of only children with no missing data. There were no significant differences in the results between the two samples. In this research we report results from the analyses of the imputed datasets.

REFERENCES

1. Olson C. Bassett Mothers Health Project: Descriptive Statistics. Funded by the National Institute of Child Health and Human Development HD29549; 1999.

2. NYSED :: IRS :: Data Reporting [Internet]. [cited 2011 Mar 26]. Available from: http://www.p12.nysed.gov/irs/data_reporting.html

3. CDC - SHPPS - School Health Policies and Practices Study - Adolescent and School Health [Internet]. [cited 2012 Feb 29]. Available from: http://www.cdc.gov/HealthyYouth/shpps/index.htm

4. Swinburn B, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. Prev Med. 1999 Dec;29(6 Pt 1):563–70.

5. Demment M. San Diego, CA; 2011.

6. WHO | Development of a WHO growth reference for school-aged children and adolescents [Internet]. WHO. [cited 2012 Jun 18]. Available from: http://www.who.int/childgrowth/publications/growthref_who_bull/en/index.html

7. Jones BL, Nagin DS, Roeder K. A SAS Procedure Based on Mixture Models for Estimating Developmental Trajectories. Sociological Methods & Research,. 2001 Feb 1;374 –393 vol. 29:

8. Nagin DS. Group-Based Modeling of Development. Harvard University Press; 2005.

9. Nagin D. Analyzing developmental trajectories: A semiparametric, group-based approach. Psychological Methods. 1999 Jun;4(2):139–57.

10. Nagin DS, Odgers CL. Group-Based Trajectory Modeling in Clinical Research. Annual Review of Clinical Psychology. 2010;6(1):109–38.

11. Weight Gain During Pregnancy: Reexamining the Guidelines [Internet]. [cited 2012 Jun 17]. Available from: http://www.nap.edu/openbook.php?record_id=12584&page=1

12. Olson CM, Strawderman MS, Dennison BA. Maternal weight gain during pregnancy and child weight at age 3 years. Matern Child Health J. 2009 Nov;13(6):839–46.

13. Kjolhede DC. 2010.

14. Common Core of Data (CCD) [Internet]. [cited 2012 Jul 9]. Available from: http://nces.ed.gov/ccd/rural_locales.asp

15. Graham JW. Missing Data Analysis: Making It Work in the Real World. Psychology. 2009 Jan;60(1):549–76.

16. Johnson DR, Young R. Toward Best Practices in Analyzing Datasets with Missing Data: Comparisons and Recommendations. Journal of Marriage and Family. 2011;73(5):926–45.

17. Allison PD. Missing Data. 1st ed. Sage Publications, Inc; 2001.

18. Buuren S van. Multiple imputation of discrete and continuous data by fully conditional specification. Stat Methods Med Res. 2007 Jun 1;16(3):219–42.

CHAPTER 3

Trajectories in family low-income and the development of overweight and obesity from birth to 15 years and their associations with early-life risk factors

ABSTRACT

Background: An emerging body of research suggests that the persistence and trajectory of a family's socioeconomic status (SES) impacts a child's health and development.

Objective: The purpose of this study was to examine the associations between family income trajectory, early-life risk factors, and BMI z-score trajectory from birth to adolescence.

Design: This longitudinal study employed a birth cohort (n=517) located in rural New York State. Data were collected through an audit of medical records and mailed questionnaires. Income and body mass index (BMI) z-score trajectories were created using latent-class modeling techniques that group children based on similar trends across time. We examined five early-life risk factors in relationship to income trajectories and BMI z-score trajectories: maternal overweight/obesity, maternal gestational weight gain, maternal smoking during pregnancy, breastfeeding duration, and early-life growth trajectory. We used multivariate multinomial logistic regression models to estimate the odds of BMI z-score trajectory membership based on income trajectory and early-life risk factors.

Results: We found that children who remain low-income throughout childhood were more likely to be in the overweight-stable trajectory (AOR=2.55, CI= 1.03 – 5.42) and children who moved into low-income during childhood were more likely to be in the obese trajectory (AOR=2.36, CI= 1.12 – 5.93) compared to children who were never low-income. Early-life risk factors that increased the odds of being in an overweight or obese trajectory were maternal overweight/obesity, excessive gestational weight gain, and high-rising early-life growth.

Conclusion: To our knowledge, this is the first study to document associations between income trajectories and developmental trajectories of overweight and obesity throughout childhood.

INTRODUCTION

Social inequalities in health are substantial in the United States and have risen over the past several decades (1,2). While there is ample evidence to suggest that poorer children do not perform as well on a wide variety of health, occupational, and educational measures, there has been inconclusive evidence to associate socioeconomic status (SES) and childhood body mass index (BMI) (3,4). One reason the estimated impact of family SES may be inconclusive is that traditional approaches to conceptualize and measure SES, typically an average of income or parental occupation, fail to capture critical aspects of the experience of low SES. An emerging body of research suggests that it is the persistence and trajectory of the family's SES, rather than the overall level of deprivation, that impacts health and development (5-7).

Therefore, it may be important to conceptualize SES using the life-course perspective, which suggests that the strength and nature of the relationship between SES and health may vary at different stages of the life-course. One feature of a life-course is trajectories. Trajectories are stable patterns of behavior or health across time (5). Typically, a person's trajectories of health, social status, etc. develop together in a consistent way and serve to reinforce each other (6). Consequently, changes in one trajectory, such as SES, may lead to changes in other trajectories, such as BMI.

The majority of studies that have examined the relationship between childhood SES and obesity have used adult populations, cross-sectional data, and one measure of childhood SES. These studies have found that childhood SES is an important predictor of adult BMI (7–15). There have been a handful of studies that have looked at the longitudinal relationship between SES and the development of obesity in children (7,16,17). All of these studies, however, looked at the change in weight status between adolescence and adulthood. While, understanding the link between childhood and adult obesity is critical, it is likely that SES has a role in the development of obesity early in life that warrants examination.

Furthermore, it is likely that SES and other risk factors co-occur, increasing a child's risk of becoming overweight or obese. The developmental origins hypothesis (18) suggests that early exposure to undernutrition or overnutrition *in utero* (19), feeding practices in infancy (20–22), smoking during pregnancy (23), and growth in early childhood (24) may play a role in the development of obesity in adult life. However, there have been few studies that have examined whether certain early-life factors pre-dispose children to certain developmental weight trajectories and none that have examined how early-life risk factors might co-exist within income trajectory.

We address these issues by investigating the longitudinal relationship between family income trajectories, early-life risk factors, and BMI z-score trajectory from 0 to 15 years, using a rural New York State birth cohort. The aims of our study are threefold. The first is to identify family income trajectories that are associated with BMI z-score trajectories from age 2 to 15 years, in the context of early-life risk factors. The second is to examine how the use of income trajectories compares to more traditional measures of SES. The third is to characterize the relationships between income trajectories and early-life risk factors. We hypothesize that children with poorer income trajectories are more likely to have early-life risk factors, compounding their likelihood of becoming overweight or obese.

SUBJECTS AND METHODS

Study sample

This study used data from the Bassett Mothers Health Project (BMHP1), an observational cohort study of 622 healthy, adult women followed from early pregnancy until 2 years postpartum. Women were recruited from the population registering for prenatal care at Bassett Healthcare's network of primary care clinics in an 8-county area of rural New York State. Additional eligibility and participation details are described elsewhere (25,26). The population for this study is the 595 (96%) full-term children born from June 1995 to July 1997. This population-based birth cohort is predominantly white (96%) with a high proportion of born to families that were low-income at the time of the birth (43%).

Data collection

This study uses data from two sources. The first source was information gathered from mothers enrolled in the BMHP1. BMHP1 was designed to examine the biological, behavioral, psychological and sociodemographic characteristics of women and the relationships of these characteristics to postpartum weight retention (27). Medical chart audits and mailed questionnaires were used to collect information on the mothers. The second source of data was retrospective medical chart audits for each full-term child. The aim of the medical chart audits was to collect information on the health and growth of the children and was completed in August 2011. The study was approved by the Institutional Review Boards of Cornell University and Bassett Healthcare.

BMI z-score trajectory: 2 to 15 years

Measured heights and weights for each child were obtained through the medical chart audits and used to derive BMI z-scores, using the World Health Organization 2007 growth standards (28). The measurements were opportunistically captured when a child went to a clinic served by the Bassett Healthcare Network. Therefore, measurement frequency and timing was different for each child. Inclusion criteria for this study was at least one BMI z-score measurement after the age 2, this reduced the sample to 87% of the population-based sample. Frequency of BMI z-score measurements was dictated largely by the regularly scheduled well-exam visits, 62% of children in the analysis sample had BMI measurements every 5 years from 2 to 15 years of age. The average number of BMI z-score measurements per child in the sample was 16 (8 SD). We used maximum-likelihood longitudinal latent-class modeling techniques to classify BMI z-score trajectory.

Family income trajectory: 0 to 15 years

Children's income trajectories were classified based on their family's movement in and out of low-income from birth to 15 years of age. Income was based on insurance codes recorded at the time of a child's visit to a clinic or hospital. A child was classified low-income if their insurance was listed as Medicaid or Child Health Plus, which requires families to have incomes 185% of the poverty line. In the sample 50% of the children had at least one income measurement every three years. We used maximum-likelihood longitudinal latent-class modeling techniques to classify family income trajectory.

Early-life risk factors

Maternal overweight/obesity category

Measured heights and weights from early pregnancy were recorded from medical chart audits as part of the BMHP1 study. Maternal overweight/obesity was classified using the Institute of Medicine BMI cutoff of $\geq$ 25 (29). Maternal overweight/obesity is a dichotomous variable (yes/no).

Gestational weight gain

Detailed gestational weight gain methods are described elsewhere (30). Briefly, the amount of weight gain was determined by subtracting the first measured weight in the first trimester of pregnancy from the weight at the last prenatal care visit, which was generally within one week of delivery. The Institute of Medicine's BMI categories and gestational weight gain guidelines were used to determine gestational weight gain category (29). Gestational weight gain is a categorical variable with three groups: excessive; inadequate; and adequate.

Maternal smoking during pregnancy

We derived smoking status during pregnancy from the medical chart audits conducted as part of the BMHP1 study. Maternal smoking during pregnancy is a dichotomous variable (yes/no).

Breastfeeding duration

Breastfeeding duration was derived from survey responses from the BMHP1 study. Breastfeeding was defined as both exclusive and partial for the purposes of this study. We chose not to use predefined cutoffs for breastfeeding duration because we were more interested in examining how the trends in breastfeeding in this population were associated with BMI z-score trajectory. Instead, women were grouped based on their similar breastfeeding duration using maximum-likelihood longitudinal latent-class modeling techniques. This allowed trends within the sample to define the categories rather than using predefined categories. Breastfeeding duration is a categorical variable with four groups: < 1 month; 1 to < 4 months; 4 to < 8 months; and ≥ 8 months.

Early-life growth trajectory

Weight-for-length z-scores were calculated for all growth data in the first two years of life using the World Health Organization 2007 growth standards (28). We used maximum-likelihood longitudinal latent-class modeling techniques to classify early-life growth trajectory. Three early-life growth trajectories were identified: high-rising (35%); low-rising (42%); and stable (23%). **Figure 3.1** illustrates the three trajectories and the proportion of children in each group.

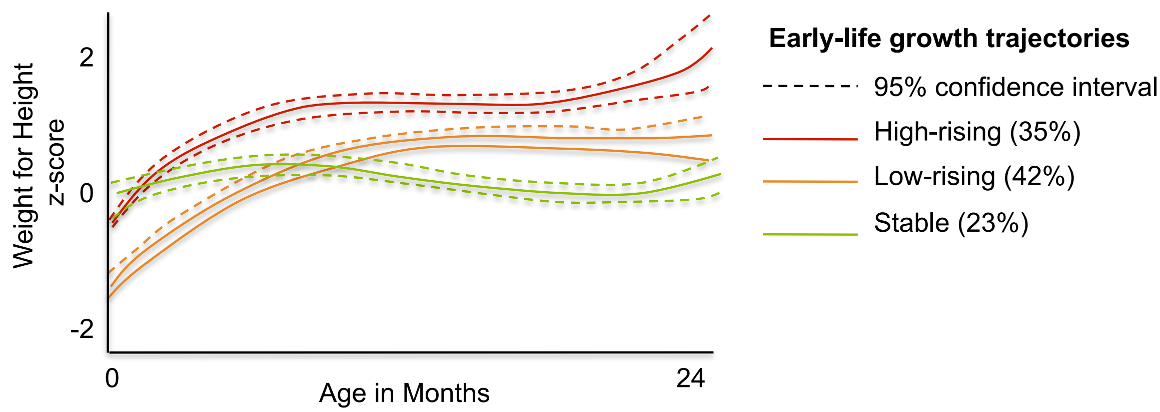


Figure 3.1. Early-life WFL z-score trajectories from 0 to 24 months

Analysis

All data analysis for this paper was conducted using SAS® software (Version 9.3, 2012, SAS Institute, Cary, NC).

BMI z-score trajectory and family income trajectory

Group-based trajectories for income from 0 to 15 years and BMI z-score 2 to 15 years were identified using maximum likelihood latent-class models in PROC TRAJ (31–34). The optimal number of trajectories were selected using the Bayesian Information Criterion (BIC) score and with the interest of parsimony (32,35). BIC does not always clearly identify a preferred number of groups. The objective of the model selection was not the maximization of BIC, rather it was to summarize the distinctive features of the data in as parsimonious a fashion as possible (32,35). The two main outputs from the trajectory models are the shape of each group's trajectory and the probabilities of group membership. The program used the latter to classify individuals into trajectory groups (34).

To determine if the frequency of the measures would bias the results we ran a complete-case model and a full model. The complete case model used only children with at least one measure every 3 years. The full model used any child with measures regardless of the frequency. One benefit of latent-class modeling is that it uses all available data to estimate the likelihood of trajectory membership. The family income trajectory membership was not statistically different for the complete-case and full models. The complete-case model for BMI z-score trajectory had a higher proportion of obese, 14% v. 12%, and "become-overweight" children, 20% v 15%, when compared to the full model. Therefore, it is likely that the findings are conservative and the inclusion of all children with BMI z-score data reduces potential bias.

BMI z-score trajectory membership based on family income trajectory and early-life risk factors

We examined all bivariate relationships between BMI z-score trajectory, family income trajectory, and potential early-life risk factors using Chi-squared analysis. All two-way interactions were also explored. We developed multivariate multinomial logistic regression models to estimate the odds of BMI z-score trajectory membership based on family income trajectory and early-life risk factors. We then used backward elimination to remove variables one at a time until each variable retained in the model had a p-value < 0.05. All models include the following maternal controls: age of mother at time of delivery (18 to <25, 25 to <29, and ≥ 30) and multiparous (yes/no). Models also included the following child controls: birthweight (1st quartile: <3264 grams, 4th quartile: $\geq$ 3945 grams, and 2nd and 3rd quartiles: 3264 to <3945 grams); sex (girl/boy); ADHD medication use (yes/no); asthma medication use (yes/no); antidepressant medication use (yes/no); and start of puberty (early, late, average).

Family income trajectory membership based on early-life risk factors

We examined all bivariate relationships between family income trajectory and early-life risk factors using Chi-squared analysis.

Missing Data and multiple imputations

Of the original sample of 595 children there are 517 with at least one BMI measurement. The baseline characteristics of the original population-based sample and the analysis sample are shown in **Table 3.1.** None of the variables of interest differ significantly across the samples and thus the analysis sample remains a reasonable one to explore our hypotheses.

Table 3.1. Baseline characteristics of population-based sample and analysis sample

	Population-based sample n=595		Analysis Sample n=517		
Income measure	%	N	%	N	p-value[a]
Low-income at birth					0.4954
Yes	44	257	43	220	
No	56	334	57	293	
Missing		4		4	
Early-life risk factors					
Maternal overweight/obesity					0.5717
Yes	50	295	49	254	
No	50	300	51	263	
Gestational weight gain					0.2798
Excessive	47	282	47	244	
Inadequate	18	106	17	88	
Within recommendations	35	207	36	185	
Smoking during pregnancy					0.8864
Yes	20	114	20	99	
No	80	477	80	414	
Missing		4		4	
Control Variables					
Multiparious					0.2302
Yes	41	243	42	216	
No	49	352	48	301	
Age category					0.1434
<25 years	26	153	27	140	
> 25 years <30 years	33	195	32	167	
> 30 years	41	247	41	210	
Birthweight					0.1718
1st quartile	26	157	25	128	
4th quartile	25	147	25	128	
2nd and 3rd quartile	49	291	50	261	
Sex					0.1167
Girl	47	278	48	248	
Boy	53	317	52	269	

*Chi-squared analysis p-value comparing analysis sample and those not included from the population sample.

Multiple imputations are recommended to reduce the potential for biased results based on excluding subjects with missing data (36). Currently, there is no consensus on the appropriateness of imputing the dependent variable (37). In the sample the dependent variable, BMI z-score trajectory, had the greatest proportion of missing data, 13%. We chose to follow the recommendations of Allison (38) and not impute the BMI z-score trajectory in this analysis because there was little missing data on income trajectory and no strongly correlated auxiliary predictors. In cases such as ours, multiple imputations for the dependent variable do not improve upon complete case analysis (38). We did use BMI z-score trajectory in the imputation process to improve the imputation process for other variables, as recommended, and then excluded children from analysis who did not have any BMI z-score measures (38). The missing data in BMI z-score trajectory was predominantly due to families moving out of the region served by the Bassett Healthcare Network before the children reach 2 years of age. However, for the small amount of missing data on early-life risk factors and controls were imputed using fully conditional specification imputation method for categorical and discrete variables in PROC MI (39), which resulted in five imputed datasets. We used Proc Logistic for the multivariate analysis and PROC MIanalyse to pool the outcomes from the five datasets. All analyses described were preformed with both the imputed datasets and a sample comprised of only children with no missing data. There were no significant differences in the results between the two samples. Therefore, in this article the results reported are from the analyses of the imputed datasets.

RESULTS

BMI z-score trajectory

Figure 3.2 illustrates the four distinct BMI z-score trajectories identified: "obese", 12% of sample, "become-overweight", 15%, "overweight-stable", 20%, and "not overweight", 53%. At 2 years of age, children in the "overweight-stable" and "obese" trajectories start off at similar BMI z-scores of about 1 (overweight). As time passes the "obese" trajectory quickly diverges from the "overweight-stable" group, peaking at around age 8 and leveling off at a BMI z-score of about 3 (obese). Children of the "not-overweight" and "become-overweight" trajectories start off at BMI z-scores of about 0 (normal weight). The "become-overweight" trajectory climbs throughout childhood, peaking at around age 12 at a BMI z-score of 1.5 (overweight), while the "not-overweight" trajectory stays relatively stable around a BMI z-core of 0.

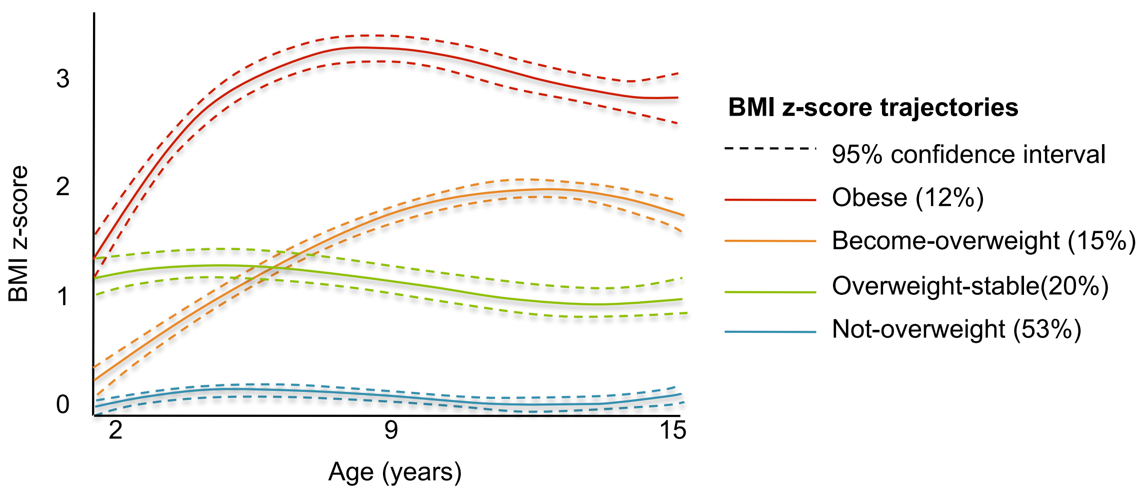


Figure 3.2. Latent-class modeling of BMI z-score trajectories, 2 to 15 years (n=517)

Variables significantly associated with BMI z-score trajectories in bivariate analysis are: income trajectory, maternal overweight/obesity, excessive gestational weight gain, smoking during pregnancy, and high-rising early-life growth trajectory.

Family income trajectory

The four income trajectories identified are illustrated in **Figure 3.3.** First, children in the "persistent low-income" trajectory comprise 12% of the sample and are characterized by having a high probability of being low-income throughout childhood. Second, children in the "downwardly-mobile" trajectory, 17% of the sample, starts off with a low probability of being low-income until about the age 7 when they begin to move into a higher probability of being low-income. Third, children in the "upwardly-mobile" trajectory, 15% of the sample, have a low probability of being low-income at birth but quickly move out of low-income by the age 8. Finally, children in the "not low-income" trajectory, 56% of the sample, have a very low probability of being low-income throughout childhood.

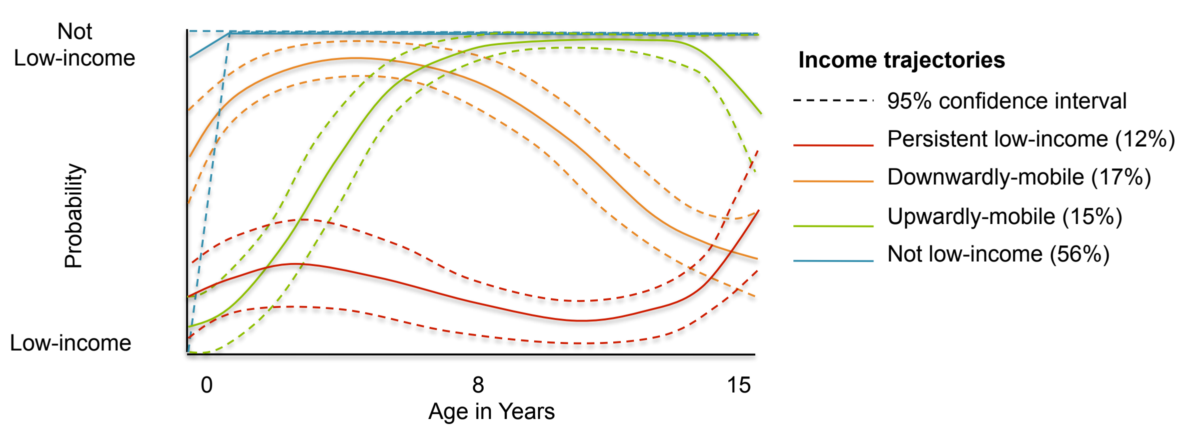


Figure 3.2. Latent-class modeling of Income trajectories, 0 to 15 years (n=517)

BMI z-score trajectory membership based on family income trajectory and early-life risk factors

Our first research aim addresses whether children with poorer income trajectories are more likely to be in an overweight or obese BMI z-score trajectory. **Table 3.2** shows the unadjusted and adjusted odds ratios from the multivariate multinomial logistic regression model. This model explained 37% (R^2) of the variance in BMI z-score trajectory membership. We found that persistent low-income children were more likely to be in the overweight-stable trajectory (OR=2.55, CI=1.03, 5.42) and downwardly-mobile children were more likely to be in the obese trajectory (OR=2.36, CI= 1.12, 5.77) compared to not-low-income children. Interesting, upwardly mobile children do not significantly differ in BMI z-score trajectory membership compared to not-low-income children.

After controlling for family income trajectory there were three early-life risk factors that were significantly associated with BMI z-score trajectory: maternal overweight/obesity, excessive gestational weight gain, and early-life growth trajectory. First, we found that maternal overweight/obesity increases the likelihood of a child being in the obese (OR=8.31, CI=3.80, 18.20), become overweight (OR=2.37, CI=1.34, 4.22), and overweight-stable trajectories (OR=1.79, CI=1.02, 3.14) compared to children in the not-overweight trajectory. Second, excessive gestational weight gain increases the likelihood of a child being in the "become-overweight" trajectory (OR=2.01, CI=1.01, 4.00) compared children in the not-overweight trajectory. Finally, both high-rising and low-rising early-life growth trajectories were associated with BMI z-score trajectory. First, children with high rising early-life growth trajectories were more likely to be in the obese trajectory (OR=5.42, CI=2.18, 13.44) and the overweight stable trajectory (OR=3.87, CI=2.07, 7.26) compared to children with stable early-life growth. Second, children with low rising early-life growth trajectories were less likely to be in the overweight stable trajectory compared to children with stable early-life growth children (OR=0.30, CI=0.15, 0.63).

Table 3.2. Odds ratios of family income trajectory and early-life risk factors for BMI z-score trajectory membership

	Obese n= 69				Become-overweight n= 92				Overweight-stable n= 119			
	Unadjusted		Adjusted[a]		Unadjusted		Adjusted[a]		Unadjusted		Adjusted[a]	
	OR	CI	OR	CI	OR	CI	OR	CI	OR	CI	OR	CI
Income trajectory												
Persistent	2.26	0.87, 5.88	1.38	0.44, 4.33	1.61	0.69, 3.88	1.33	0.53, 3.33	**3.00**	**1.51, 5.98**	**2.55**	**1.03, 5.42**
Downwardly-mobile	**2.99**	**1.51, 5.93**	**2.36**	**1.12, 5.77**	1.22	0.61, 2.43	1.04	0.50, 2.18	0.95	0.48, 1.90	0.82	0.38, 1.79
Upwardly-mobile	1.62	0.74, 3.52	1.15	0.46, 2.92	0.73	0.33, 1.61	0.59	0.25, 1.39	0.89	0.45, 1.77	0.68	0.31, 1.50
Not low-income	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Maternal overweight/obesity												
Yes	**7.02**	**3.57, 13.77**	**8.31**	**3.80, 18.2**	**2.85**	**1.69, 4.78**	**2.37**	**1.34, 4.22**	**1.59**	**1.00, 2.51**	**1.79**	**1.02, 3.14**
No	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Gestational weight gain												
Excessive	1.21	0.67, 2.19	0.49	0.23, 1.05	**2.37**	**1.28, 4.38**	**2.01**	**1.01, 4.00**	0.82	0.50, 1.35	0.61	0.33, 1.12
Inadequate	0.56	0.28, 1.40	0.58	0.21, 1.66	1.53	0.70, 3.33	1.47	0.64, 3.37	0.54	0.27, 1.08	0.68	0.31, 1.50
Adequate	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Early-life growth trajectory												
High-rising	**7.03**	**3.05, 16.22**	**5.42**	**2.18, 13.44**	1.71	0.84, 3.49	1.64	0.77, 3.49	**3.32**	**1.85, 5.96**	**3.87**	**2.07, 7.26**
Low-rising	0.77	0.31, 1.95	**0.50**	**0.19, 1.36**	1.00	0.54, 1.89	0.90	0.46, 1.77	**0.29**	**0.14, 0.58**	**0.30**	**0.15, 0.63**
Stable	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Smoking during pregnancy[b]												
Yes	**2.18**	**1.18, 4.03**	-	-	0.84	0.42, 1.67	-	-	1.37	0.78, 2.39	-	-
No	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Breastfeeding duration[b]												
< 2 months	1.59	0.79, 3.20	-	-	1.09	0.59, 2.04	-	-	1.04	0.59, 1.84	-	-
2 to < 4 months	1.23	0.48, 3.12	-	-	1.19	0.54, 2.64	-	-	0.82	0.38, 1.80	-	-
4 to < 8 months	0.64	0.25, 1.63	-	-	0.64	0.29, 1.41	-	-	0.81	0.41, 1.57	-	-
≥ 8 months	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-

Reference category for BMI z-score trajectory is not-overweight (n= 315)

[a]Odds ratios are adjusted for multiparious, maternal age, sex of child, birth weight quartile, asthma medication use, add medicaiton use, antidepressant medication use

[b] Smoking during pregnancy and breastfeeding duration were removed from the multivariate model during the backward elmination procedure.

Our second research aim addressed whether income trajectories captured more of the variation in BMI z-score trajectory membership than traditional measures of SES. We replaced income trajectories in the model by low-income at birth, low-income in adolescence, ever low-income, and maternal education. As shown in **Table 3.3** none of these SES measures was significantly associated with BMI z-score trajectory membership and each reduced the amount of variance explained by the model by about 2%.

Table 3.3. Associations between BMI z-score trajectory and different SES measures

	p-value[a] for SES measure	R^2
Model A	-	35.2
Model A + income trajectories	0.038	37.7
Model A + low-income at birth	0.802	35.4
Model A + low-income in adolescence	0.324	35.7
Model A + ever low-income	0.469	35.6
Model A + maternal education	0.266	36.3

Note: Model A includes maternal overweight/obesity, gestational weight gain, early-life growth trajectory, multiparous, maternal age, sex of child, birth weight quartile, asthma medication use, add medication use, antidepressant medication use
[a]Type 3 Analaysis of Effects p-value

Family income trajectory membership based on early-life risk factors

Our final research aim was to characterize the income trajectories based on early-life risk factors. We did not hypothesize that early-life risk factors cause family income trajectory, merely that certain early-life risk factors were more highly concentrated in the low-income trajectories. **Table 3.4** shows the bivariate associations between income trajectories, early-life risk factors, and control variables. For this analysis the not-low-income trajectory served as the comparison group. Higher proportions of excessive maternal gestational weight gain and maternal smoking during pregnancy were seen in all of the low-income trajectories. Mothers also tended to be younger in the low-income trajectories. We also saw differences in early-life risk factors by family income trajectory. Persistent low-income children were more likely to have higher proportions of maternal overweight/obesity and breastfed for less than 1 month. Persistent low-income children also tended to have higher proportions of ADHD medication use and asthma medication use. Downwardly-mobile children were more likely to have higher proportions of maternal overweight/obesity and high-rising early-life growth trajectories, while upwardly-mobile children were more likely to be breastfed for less than 1 month and have high-rising early-life growth trajectories.

Table 3.4. Associations between family income trajectory membership, early-life risk factors, and control variables

	Not low-income		Persistent				Downwardly-mobile				Upwardly-mobile			
	n=332		n=68				n=102				n=93			
	%	N	%	N	p-value[a]		%	N	p-value[b]		%	N	p-value[c]	
Early-life risk factors														
Maternal overweight/obesity					0.0463	**			0.051	*			0.2391	
Yes	44	132	59	33			56	49			52	40		
No	56	165	41	23			44	38			48	37		
Gestational weight gain					0.0962	*			0.06726	*			0.0016	***
Excessive	43	142	50	34			47	48			62	58		
Inadequate	17	57	24	16			18	18			16	15		
Adequate	40	133	26	18			35	36			22	20		
Smoking during pregnancy					<0.0001	***			0.0031	***			<0.0001	***
Yes	12	39	37	25			24	24			32	30		
No	88	293	63	43			76	78			68	63		
Breastfeeding duration					0.0563	*			0.1913				0.0834	*
< 2 months	35	116	49	33			45	46			48	45		
2 to < 4 months	14	46	16	11			14	14			10	9		
4 to < 8 months	23	76	10	7			14	15			23	21		
≥ 8 months	28	94	25	17			27	27			19	18		
Early-life growth trajectory					0.2655				0.0455	**			0.0816	*
High-rising	26	86	34	23			35	36			38	35		
Low-rising	52	171	41	28			52	53			42	39		
Stable	22	75	25	17			13	13			20	19		
Control Variables														
Multiparious					0.2011				0.9264					
Yes	41	135	32	22			41	42			47	44	0.251	
No	59	197	68	46			59	60			53	49		
Age category					<0.0001	***			0.0001	***			<0.0001	***
<25 years	15	51	40	27			33	34			44	41		
> 25 years <30 years	34	114	26	18			33	34			31	29		
> 30 years	50	167	34	23			33	34			25	23		
Birthweight					0.699				0.3182				0.3701	
1st quartile	27	79	23	13			20	18			26	27		
4th quartile	24	69	28	16			22	20			31	24		
2nd and 3rd quartile	49	145	49	28			58	52			43	50		
Sex					0.5729				0.9566				0.3723	
Girl	46	154	43	29			46	47			52	48		
Boy	54	178	57	39			54	55			48	45		
Start of puberty					0.6203				0.2199				0.9508	
Early	20	65	15	10			15	14			18	17		
Late	21	69	21	14			27	28			21	19		
Middle	59	198	65	44			59	60			61	57		
ADHD medication use					0.0026	**			0.2426				0.3077	
Yes	5	16	15	10			8	8			8	7		
No	95	316	85	58			92	94			92	86		
Asthma medication use					0.2089				0.1164				0.8298	
Yes	18	61	25	17			25	26			19	18		
No	82	271	75	51			75	76			81	75		
Antidepressant medication use					0.0577	*			0.2733				0.791	
Yes	3	9	7	5			5	5			3	3		
No	97	323	93	63			95	97			97	90		

[a]Chi-square analysis comparing persisent low-income children to not low-income children
[b]Chi-square analysis comparing downwardly-mobile children to not low-income children
[c]Chi-square analysis comparing upwardly-mobile children to not low-income children
Signifcance at <0.1 = *; <0.05 = **, and <0.01 = ***

DISCUSSION

This study was undertaken to assess the association between family income trajectory, early-life risk factors, and BMI z-score trajectory from birth to adolescence. The study is unique because family income trajectory has not been considered in previous studies examining the relationship between SES and the development of overweight and obesity. Our main finding is that children who are persistently low-income were more likely to have a stable BMI z-score in the overweight range. While, children who move *into* low-income were more likely to have a BMI z-score in the obese range. Interestingly, we found that children who moved *out* of low-income were *not* more likely to be overweight or obese compared to children who did not experience low-income. This finding was contrary to previous studies that have found a strong correlation between low-income in early childhood and obesity in later life (7–15). There are two potential explanations for this finding. First, the use of a longitudinal measure for income allows us to disentangle "persistent low-income" children from "upwardly mobile" children and capture their potentially different experiences. Alternatively, the effects of early childhood low-income may not have appeared in the cohort by the age 15.

The mechanisms that could produce obesity in children who move into low-income compared to the overweight in children who are persistently low-income are likely different. We propose that the life events that cause a family to move into low-income, such as divorce or loss of job, may put these children in new and/or stressful environments. In the future, it would be helpful to know how the nutrition and physical activity of families with downward mobility change during times of economic transition. Furthermore, these findings highlight the need for assistance programs to support and encourage healthy eating and physical activity during times of economic downturn.

Our secondary finding, that family income trajectory captures more variation in BMI z-score trajectory membership than other measures of SES, is important for future work. Some researchers suggest that income is perhaps the strongest and most robust SES predictor of health (40,41) because the impacts of other SES variables are mediated through it (42). However, income is often only measured once and this can be problematic, especially given how dynamic income is in the United States. Rank and Hirschl (43) estimate, using 25 waves of the Panel Study of Income Dynamics, that 51% of adults, age 25 to 75, will spend at least one year in poverty; while 51% will spend at least one year in affluence; and 22% live at least one year in both. We demonstrate similar dynamics in the sample, with 43% experiencing low-income during their childhood and 32% showing mobility either in or out of low-income. The use of traditional measures of SES may contribute to residual confounding in analyses and may be masking or overstating associations between risk factors and childhood obesity. When possible, multiple measures of income over time are warranted to better understand the development of overweight and obesity in cohorts.

Our final contribution is that we add to the growing evidence that early-life risk factors are strongly associated with the development of overweight and obesity in children. To our knowledge, two other studies (44,45) have examined childhood BMI trajectories in association with early-life risk factors. The first study by Li and colleagues (44) used 6 assessment points from age 2 to 12 years and identified three developmental trajectories of overweight status among a representative US sample (n= 1739): early onset (age 2 years, 10.9%), late onset (age 6 years, 5.2%), and never overweight (83.9%). They found associations between BMI trajectory and two early-life risk factors: maternal overweight/obesity and excessive gestational weight gain. They did not find a significant association between BMI trajectory and maternal smoking during pregnancy or breastfeeding duration. They did not examine early-life growth. They used maternal education and family income at one time period to capture SES. Neither of these variables was significantly associated with the odds of BMI trajectory membership. The second study by Pryor and colleagues (45) used 8 assessment points from 6 months to 8 years and identified three development trajectories of overweight status among a representative Canadian sample (n= 1957): low-stable (54.5%), moderate (41.0%), and high-rising (4.5%). They found associations between BMI trajectory and two early-life risk factors: maternal overweight/obesity and maternal smoking during pregnancy. They did not find a significant association between BMI trajectory and breastfeeding duration or early-life growth. They did not examine gestational weight gain. To approximate SES they used a dichotomous measure of low-income at one time period, maternal education, and family functioning. None of these measures of SES was significantly associated with the odds of BMI z-score membership.

In this study we explore five early-life risk factors in the context of a more multidimensional measure of SES. Our findings that maternal overweight/obesity, excessive gestational weight gain and high-rising early-life growth trajectories are significantly associated with BMI trajectory support the findings of the previous two studies. To better understand the two non-significant findings smoking during pregnancy and breastfeeding duration we conducted follow-up analyses. Since birth weight and smoking during pregnancy are strongly correlated, we removed birth weight from the model and found that smoking during pregnancy became significant. This suggests that the effects of smoking during pregnancy were mediated in part by birth weight. While previous studies (20–22) have found a relationship between breastfeeding duration and overweight and obesity, we did not. In further analyses we found a trend between breastfeeding duration, family income trajectory and early life growth. Children who were persistently low-income and breastfed for longer durations were *less* likely to be in the "high-rising" early-life growth trajectory ($p= 0.07$). Future studies to examine how the effect of breastfeeding on risk of overweight and obesity varies by SES status are warranted.

Our study is strengthened by five methodological components. First, we use an at-risk, understudied rural population. The sample had considerably higher rates of overweight and obesity compared to the two other studies (44,45) that have looked at BMI trajectories. Second, we examined the development of overweight and obesity over the span of 15 years. Third, we have relatively low attrition. The free school-based clinics and a multi-site healthcare system mitigate against some attrition and facilitates the retention of more low-income children in this study. Usually low-income children are less likely to receive healthcare but in this system, school-aged children are seen at no cost in the school-based clinics. The loss to follow-up is therefore reduced and the maintenance of more low-income adolescents in the study reduces bias. Fourth, we used measured weights and heights to define BMI z-score trajectories over time. The results are more reliable than those using self-reported weight and height. Fifth, we use advanced statistical modeling to create income and BMI z-score trajectories allowing us to group children based on their similar movements in time.

Our findings should be considered in the context of its limitations. First, the measure of low-income was defined by being below 185% of the poverty line based on insurance code. The dichotomous measure of income may mask important differences within the income range. Second, the use of medical records for the data collection on growth and income was opportunistic. We only have measures when children attended a clinic or hospital. Third, the sample was predominantly white and rural and the findings are limited to similar populations. Fourth, this cohort spans 3 years of births. It is likely that their income and weight patterns are affected by the historical context they grew up in. Finally, our research was not able to explore any potential mechanisms linking SES to overweight and obesity. There are several potential mechanisms linking SES and childhood obesity, that warrant greater research and intervention, such as food insecurity, parenting style, household stress, neighborhood characteristics, school characteristics, exposure to food advertising, fruit and vegetable consumption, fast-food consumption, opportunities for physical activity, sports participation, and time spent outdoors (46). Future research is needed to identify income trajectories in more nationally representative samples and to examine their associations with BMI z-score trajectory, while also exploring potential mechanisms that help us understand how changes in trajectories occur.

Conclusion

Disentangling the relationship between SES, early-life risk factors, and the development of overweight and obesity is challenging. To address this problem we used a novel measure of SES that simultaneously captures multiple dimensions of income including duration, timing, and sequencing. Our work highlights the unadjusted and adjusted associations between income status and early-life risk factors on the development of overweight and obesity. Our findings suggest that overweight and obesity develops early in life, with distinguishable BMI z-score trajectories occurring in early childhood and carrying on through adolescence. Our work further supports the growing evidence that there are several preventable early-life risk factors that could be targeted for intervention. However, in our sample, income trajectories and early-life-risk factors are independently associated with the development of overweight and obesity. Therefore, considering the role of SES, not simply individual risk factors, will be critical for the development of policies and interventions that reach a greater number of at-risk children.

REFERENCES

1. Singh GK, Siahpush M. Widening socioeconomic inequalities in US life expectancy, 1980-2000. Int. J. Epidemiol. 2006 Aug 1;35(4):969–79.

2. National Center for Health Statistics. Health, United States, 2008 with Special Feature on the Health of Young Adults. Hyattsville, MD: US Department of Health and Human Services; 2009.

3. Chang VW, Lauderdale DS. Income disparities in body mass index and obesity in the United States, 1971-2002. Arch. Intern. Med. 2005 Oct 10;165(18):2122–8.

4. Wang Y, Zhang Q. Are American children and adolescents of low socioeconomic status at increased risk of obesity? Changes in the association between overweight and family income between 1971 and 2002. Am. J. Clin. Nutr. 2006 Oct;84(4):707–16.

5. Wethington E. An Overview of the Life Course Perspective: Implications for Health and Nutrition. Journal of Nutrition Education and Behavior. 2005 May;37(3):115–20.

6. Damon W, Lerner RM. Handbook of Child Psychology: Theoretical models of human development. John Wiley and Sons; 2006.

7. Scharoun-Lee M, Kaufman JS, Popkin BM, Gordon-Larsen P. Obesity, race/ethnicity and life course socioeconomic status across the transition from adolescence to adulthood. Journal of Epidemiology and Community Health. 2009 Feb 1;63(2):133 –139.

8. Olson CM, Bove CF, Miller EO. Growing up poor: long-term implications for eating patterns and body weight. Appetite. 2007 Jul;49(1):198–207.

9. Goldblatt PB, Moore ME, Stunkard AJ. Social Factors in Obesity. JAMA. 1965 Jun 21;192(12):1039–44.

10. Laaksonen M, Sarlio-Lahteenkorva S, Lahelma E. Multiple Dimensions of Socioeconomic Position and Obesity among Employees: The Helsinki Health Study[ast][ast]. Obesity. 2004 Nov;12(11):1851–8.

11. Langenberg C, Hardy R, Kuh D, Brunner E, Wadsworth M. Central and total obesity in middle aged men and women in relation to lifetime socioeconomic status:

evidence from a national birth cohort. Journal of Epidemiology and Community Health. 2003 Oct 1;57(10):816 –822.

12. Lissau I, Sorensen TIA, Lissau I. Parental neglect during childhood and increased risk of obesity in young adulthood. The Lancet. 1994 Feb 5;343(8893):324–7.

13. Poulton R, Caspi A, Milne B, Thomson W, Taylor A, Sears M, et al. Association between children's experience of socioeconomic disadvantage and adult health: a life-course study. The Lancet. 2002 Nov;360(9346):1640–5.

14. Power C, Graham H, Due P, Hallqvist J, Joung I, Kuh D, et al. The contribution of childhood and adult socioeconomic position to adult obesity and smoking behaviour: an international comparison. International Journal of Epidemiology. 2005 Apr;34(2):335 –344.

15. Power C, Manor O, Matthews S. Child to adult socioeconomic conditions and obesity in a national cohort. Int. J. Obes. Relat. Metab. Disord. 2003 Sep;27(9):1081–6.

16. Wells NM, Evans GW, Beavis A, Ong AD. Early childhood poverty, cumulative risk exposure, and body mass index trajectories through young adulthood. Am J Public Health. 2010 Dec;100(12):2507–12.

17. Lee H, Harris KM, Gordon-Larsen P. Life Course Perspectives on the Links Between Poverty and Obesity During the Transition to Young Adulthood. Popul Res Policy Rev. 2009 Aug 1;28(4):505–32.

18. Oken E, Gillman MW. Fetal origins of obesity. Obes. Res. 2003 Apr;11(4):496–506.

19. Oken E. Maternal and child obesity: the causal link. Obstet. Gynecol. Clin. North Am. 2009 Jun;36(2):361–377, ix–x.

20. Gillman MW, Rifas-Shiman SL, Camargo CA, Berkey CS, Frazier AL, Rockett HRH, et al. Risk of Overweight Among Adolescents Who Were Breastfed as Infants. JAMA. 2001 May 16;285(19):2461–7.

21. Hediger ML, Overpeck MD, Kuczmarski RJ, Ruan WJ. Association between infant breastfeeding and overweight in young children. JAMA. 2001 May 16;285(19):2453–60.

22. von Kries R, Koletzko B, Sauerwald T, von Mutius E, Barnert D, Grunert V, et al. Breast feeding and obesity: cross sectional study. BMJ. 1999 Jul 17;319(7203):147–50.

23. Howe LD, Matijasevich A, Tilling K, Brion M-J, Leary SD, Davey Smith G, et al. Maternal smoking during pregnancy and offspring trajectories of height and adiposity: comparing maternal and paternal associations. International journal of epidemiology. 2012 Mar 9;

24. Baird J. Being big or growing fast: systematic review of size and growth in infancy and later obesity. BMJ. 2005 Oct 22;331(7522):929–0.

25. Hinton PS, Olson CM. Predictors of pregnancy-associated change in physical activity in a rural white population. Matern Child Health J. 2001 Mar;5(1):7–14.

26. Kendall A, Olson CM, Frongillo EA. Evaluation of psychological measures for understanding weight-related behaviors in pregnant women. Ann Beh Med. 2001;23(1):50–8.

27. Olson C. Bassett Mothers Health Project: Descriptive Statistics. Funded by the National Institute of Child Health and Human Development HD29549; 1999.

28. WHO | WHO Child Growth Standards: Methods and development [Internet]. WHO. [cited 2012 Jun 18]. Available from: http://www.who.int/childgrowth/publications/technical_report_velocity/en/index.html

29. Weight Gain During Pregnancy: Reexamining the Guidelines [Internet]. [cited 2012 Jun 17]. Available from: http://www.nap.edu/openbook.php?record_id=12584&page=1

30. Olson CM, Strawderman MS, Dennison BA. Maternal weight gain during pregnancy and child weight at age 3 years. Matern Child Health J. 2009 Nov;13(6):839–46.

31. Jones BL, Nagin DS, Roeder K. A SAS Procedure Based on Mixture Models for Estimating Developmental Trajectories. Sociological Methods & Research. 2001 Feb 1;29(3):374–93.

32. Nagin DS. Group-Based Modeling of Development. Harvard University Press; 2005.

33. Nagin D. Analyzing developmental trajectories: A semiparametric, group-based approach. Psychological Methods. 1999 Jun;4(2):139–57.

34. Nagin DS, Odgers CL. Group-Based Trajectory Modeling in Clinical Research. Annual Review of Clinical Psychology. 2010;6(1):109–38.

35. Jones BL, Nagin DS, Roeder K. A SAS Procedure Based on Mixture Models for Estimating Developmental Trajectories. Sociological Methods & Research,. 2001 Feb 1;374 –393 vol. 29:

36. Graham JW. Missing Data Analysis: Making It Work in the Real World. Psychology. 2009 Jan;60(1):549–76.

38. Allison PD. Missing Data. 1st ed. Sage Publications, Inc; 2001.

39. Buuren S van. Multiple imputation of discrete and continuous data by fully conditional specification. Stat Methods Med Res. 2007 Jun 1;16(3):219–42.

40. McDonough P, Duncan GJ, Williams D, House J. Income dynamics and adult mortality in the United States, 1972 through 1989. Am J Public Health. 1997 Sep;87(9):1476–83.

41. Lantz PM. Socioeconomic Factors, Health Behaviors, and Mortality: Results From a Nationally Representative Prospective Study of US Adults. JAMA: The Journal of the American Medical Association. 1998 Jun 3;279(21):1703–8.

42. Brian D. Smedley and S. Leonard Syme, Editors; Committee on Capitalizing on Social Science and Behavioral Research to Improve the Public's Health, Division of Health Promotion and Disease Prevention. Promoting Health: Intervention Strategies from Social and Behavioral Research. Washington, D.C.: The National Academies Press; 2000.

43. Rank MR, Hirschl TA. Rags or Riches? Estimating the Probabilities of Poverty and Affluence across the Adult American Life Span. Social Science Quarterly. 2001;82(4):651–69.

44. Li C, Goran MI, Kaur H, Nollen N, Ahluwalia JS. Developmental trajectories of overweight during childhood: role of early life factors. Obesity (Silver Spring). 2007 Mar;15(3):760–71.

45. Pryor LE, Tremblay RE, Boivin M, Touchette E, Dubois L, Genolini C, et al. Developmental trajectories of body mass index in early childhood and their risk factors: an 8-year longitudinal study. Arch Pediatr Adolesc Med. 2011 Oct;165(10):906–12.

46. Yancey AK, Kumanyika SK. Bridging the Gap: understanding the structure of social inequities in childhood obesity. Am J Prev Med. 2007 Oct;33(4 Suppl):S172–174.

CHAPTER 4

Food insecurity, early-life risk factors, and rate of growth among children: a longitudinal study from birth to 15 years

ABSTRACT

Background: Longitudinal studies that examine the relationship food insecurity and weight status have found contradicting and inconclusive results.

Methods: We used longitudinal data from an rural New York State birth cohort to determine whether rates of growth in infancy, 0 to 2 years, and childhood, 2 to 15 years, differ by exposure to three different measures of food insecurity: 1) food insecurity status before birth; 2) food insecurity status at 2 years; and 3) a longitudinal measure of food insecurity from before birth to 2 years.

Results: We used linear mixed models to estimate rate of growth during infancy and childhood. We found that food-insecure children compared to food-secure children, were smaller in early childhood but due to increased rate of growth by the time food-insecure children reach 15 years of age they had higher BMI z-scores.

Conclusion: We provide evidence that children who experience food insecurity early in life have steeper rates of growth compared to food-secure children. Our findings

provide new insight into why longitudinal studies in early childhood have been inconclusive.

INTRODUCTION

One in five U.S. households with children experienced food insecurity in 2010 (1). Food insecurity disproportionately affects children and families at highest risk for obesity (1). Initially perceived as separate health problems, there is growing concern that food insecurity, a condition of insufficiency and undernutrition, and obesity, a condition of overnutrition, are related. It has been proposed that food insecurity may lead to weight gain because the least expensive food options are typically high in calories and low in nutrients (2,3). Research suggests that high-calorie foods are easy to over-consume and promote weight gain if they are part of a regular diet (4,5). Households with limited resources tend to spend less on food as a part of their overall budget and less money on healthy foods that are lower in energy and more costly (e.g., fruits and vegetables) (3).

The challenge to researchers is to disentangle whether food insecurity merely coexists with other risk factors for childhood obesity or if they are linked along a causal pathway. One way to do this is to use longitudinal data, which have clear analytical advantages over cross-sectional data. First, the temporal nature allows for measurement of change over time. Temporality insures that the outcome is associated with the initial exposure status and not due to reverse causality. In this case, reverse causality could be that larger kids may consume more food to meet their energy requirements, thus increasing the likelihood of their families being food insecure. Second, the investigation of within-person changes reduces the effects of unmeasured confounders. To examine the relationship between food insecurity and growth in children, longitudinal data provide the best design to establish that observed effects are causal and not due to reverse causality or confounding (6).

Only five longitudinal studies (7–11) have examined the relation between household food insecurity and growth among US children since the year 2000 (12). Four of these studies (7–10) used the same nationally representative sample, Early Childhood Longitudinal Study-Kindergarten cohort, to examine the relationship between food insecurity and growth in children from kindergarten to 3rd grade. Only one study (7) found evidence to indicate that girls in food-insecure households are more likely to be obese or experience greater gains in body mass index (BMI) over time compared with girls who are food secure. The remaining studies found no evidence of a direct relationship between household food insecurity and growth or found evidence indicating that children living in food-insecure households are less likely to be obese (8–10). The other longitudinal study by Bronte-Tinkew and colleagues (11) used the Early Childhood Longitudinal Study-Birth Cohort and found an indirect association between food insecurity and overweight at 2 years, which operated through parenting and infant feeding practices.

While the findings of these studies do not support a direct association between food insecurity and BMI in early childhood, key questions remain. First, does food insecurity affect BMI later in development, beyond 5th grade? The effects of food insecurity may not take effect this early in children. Exploring the relationship between food insecurity and growth at a later time period is warranted. Second, does food insecurity affect the *rate* of change in growth and not simply the change in growth? There is strong evidence that links rapid weight gain in early childhood to risk for overweight and obesity later in life (13). Examining the rate change in growth may elucidate important differences in growth that are masked when just overall change in growth is used. Third, do children who transition from food-secure to food-insecure have different growth patterns compared to children who transition from food-insecure to food-secure? This type of comparison could help us understand if changes in food security are related to changes in growth. Comparative data of this nature would allow us to infer greater causality.

To address these questions we used longitudinal data from a rural New York State birth cohort (n=517) to determine whether changes in food insecurity from early pregnancy to 2 years are associated with rate change (slope) in growth during two developmental stages: infancy (0 to <2 years) and childhood (2 to 15 years). The objectives of our study are twofold. First, we examined those early-life risk factors for overweight and obesity that co-exist in food-insecure families. Second, we investigated whether rates of growth in infancy and childhood differ across three different measures of food insecurity: 1) food insecurity status before birth; 2) food insecurity status at 2 years; and 3) a longitudinal measure of food insecurity from before birth to 2 years. We hypothesize that the timing and transitions in food insecurity have different consequences for growth.

SUBJECTS AND METHODS

Data

This study is an observational, epidemiological study with a cohort design and includes two sources of data. The first source is information gathered from mothers enrolled in the Bassett Mothers Health Project 1 (BMHP1) who gave birth to a child from June 1995 to July 1997, in an 8-county region of rural upstate New York State. BMHP1 was designed to examine the biological, behavioral, psychological, and sociodemographic characteristics of women and the relationships of these characteristics to postpartum weight retention. Women were followed from the second trimester of pregnancy until two years postpartum. Of the 622 women enrolled in the study, 595 delivered full term infants with a gestational age $\geq$ 37 weeks. The second source of data is retrospective medical chart audits for each child, born to a mother from the BMHP1, through the Bassett Healthcare Network. The aim of the medical chart audits was to collect information on the health and growth of the children. A final audit was completed in August 2011.

The study was approved by the Institutional Review Boards of Cornell University and Bassett Healthcare.

Sample

Our two analytic samples consisted of the following: 1) infancy sample with at least one weight-for-length (WFL) z-score measures from 0 to <2 years; and 2) childhood sample with BMI z-scores from 2 to 15 years. These two time periods were selected because they reflect the concurrent growth associated with early-life food insecurity path and the subsequent growth available in the cohort.

WFL z-score and BMI z-score

WFL z-score and BMI z-score are continuous variables calculated based on the heights and weights recorded in the medical records. The World Health Organization 2007 growth standards were used to calculate WFL z-scores and BMI z-scores (14). All z-scores were graphically represented for each child and checked visually for abnormalities. Any abnormalities are flagged and checked in the medical records for accuracy. The frequency of growth measurements was dictated largely by the regularly scheduled well-exam visits but the timing was different for each child.

Food insecurity path

At the time when women enrolled in BMHP1, 1994-1996, food insecurity was measured using three items included in the women's medical records from the Institute of Medicine's nutritional questionnaire (15). At two years postpartum, food insecurity was measured using three questions from the US Household Food Security Survey (16) that were included in a mailed questionnaire. The US Household Food Security Survey was developed in 1995 and therefore was not available for the early pregnancy measurement of food security in the sample. The items used at each time point are shown in **Table 4.1** and were judged by the research team to be conceptually similar. A positive response to any one of these questions was considered indicative of food security.

Table 4.1. Items used for assessing food insecurity in early pregnancy and at 2 years postpartum

Early Pregnancy	2 years of age
The responses to each of these items below were yes or no:	*The responses to each of the items below were "not true," "sometimes true," or "often true:"*
1. Do you sometimes run out of food before you are able to buy more?	1. I worried whether my food would run out before I got money to buy more.
2. Can you afford to eat the way you should?	2. We couldn't eat balanced meals because we couldn't afford that.
3. Do you need help obtaining food?	3. The food that I bought didn't last, and I didn't have money to buy more.

Food insecurity data at both time points were available for 348 children (67.2% of analysis sample) with 502 children (95.1%) having at least one measure of food insecurity. Detailed information about the differences in complete vs. missing case samples is available elsewhere (17). Briefly, when the complete case sample was compared to those with missing data there were no significant differences across the variables of interest. We chose to impute missing data pertaining to food insecurity to reduce the potential for biased results based on excluding subjects with missing data (18). **Table 4.2** shows the difference in prevalence of food insecurity between the imputed and original sample. The imputed sample has higher rates of food insecurity at both time points.

Table 4.2. Differences in prevalence of food insecurity between imputed sample (n=517) and complete-case sample (n=348)

Food insecurity path	Imputed sample n= 517	Complete-case sample n=348
Stay	58 (11.2%)	34 (9.8%)
Become	70 (13.5%)	41 (11.8%)
Move out of	63 (12.2%)	26 (7.5%)
Never	326 (63.1%)	247 (70.8%)

We used three food insecurity variables in the analysis: 1) *food insecurity in early pregnancy* (yes/no); 2) *food insecurity at 2 years of age* (yes/no); and 3) *food insecurity path* (stay food insecure; become food insecure; move out of food insecurity; and food secure).

Risk factors

Given that children who live in food insecure households are more likely to have other risk factors for overweight and obesity, the inclusion of individual, maternal, and household risk factors in the analysis reduced the possibility of spurious associations between the variables of interest. The following variables were included in the analysis.

High-perceived stress. Stress was measured twice, when the child was one and two years, through mailed questionnaires. Mother's were asked, "How stressful is your life right now?" They could answer: very stressful, somewhat stressful, not very stressful, and not at all stressed. If they answered very stressful at either time period they were classified as high-perceived stressed. High-perceived stress is a dichotomous variable (yes/no).

Family income trajectory. Children's income trajectories are classified based on their family's movement in and out of low-income during three time periods: infancy, early childhood, and late childhood. Income is based on insurance codes recorded at the time of a child's visit. A child is classified as low-income if their insurance was listed as Medicaid or Child Health Plus, which require families be below 185% of the poverty line. Family income trajectory is derived from maximum-likelihood, longitudinal, latent-class modeling techniques. This group-based modeling strategy determines the probability of children's low-income over time and simultaneously considers timing, duration, and sequencing. Income trajectories are estimated using PROC TRAJ (19,20). The optimal number of trajectories is chosen on the basis of the Bayesian Information Criterion (BIC) score and an examination of the 95% confidence interval of adjacent trajectories.

Maternal overweight/obese. Maternal BMI is a dichotomous variable (yes/no). Measured heights and weights from early pregnancy are recorded from medical chart audits as part of the BMHP1 study. Maternal body weight was classified overweight/obese using the Institute of Medicine BMI cutoff (21) of BMI >25.0.

Gestational weight gain. Gestational weight gain is a categorical variable (excessive, inadequate, and adequate). The amount of weight gain was determined by subtracting the first measured weight in the first trimester of pregnancy from the weight at the last prenatal care visit which was generally within one week of delivery. Gestational weight gain category was defined according to the IOM BMI categories and gestational weight gain guidelines (21).

Maternal Smoking during Pregnancy. Maternal smoking during pregnancy is a dichotomous variable (yes/no). We derive smoking status during pregnancy from the medical chart audits conducted as part of the BMHP1 study.

Breastfeeding Duration. Breastfeeding duration is a dichotomous variable (< 4 months and ≥ 4 months). Breastfeeding duration is derived from survey responses from the BMHP1 study. Breastfeeding was defined as both exclusive and partial for the purposes of this study.

Other potential confounders. All models include the following maternal controls: *maternal education* (High school or less, some college or technical school, and college or more), *age of mother at time of delivery* (18 to <25, 25 to <29, and $\geq$ 30), *marital status* (single/married), and *multiparous* (yes/no). Models also included the following child controls: *sex* (girl/boy) and for late childhood models *ADHD medication use* (yes/no); *asthma medication use* (yes/no); *antidepressant medication use* (yes/no); and *start of puberty* (early, late, average).

Analysis

Co-existing risk factors for obesity and food insecurity

We used multinomial logistic regression to estimate the likelihood of being food insecure based on maternal and household risk factors. We used reverse backward elimination and removed non-significant variables one at a time until each variable retained in the model had a p-value < 0.20.

Change in growth during infancy and childhood

We developed multivariate linear mixed models to predict growth in infancy and childhood using Proc Mixed in SAS software (Version 9.3, 2012, SAS Institute, Cary, NC). We used a random-slope and random-intercept model. Random effects are used to model between-subject variation and the correlation induced by this variation. There are two forms of linear-mixed models: 1) random intercept models, which account for children having different baseline measurements (e.g., not all children had the same WFL z-score at birth) and 2) random intercept and slope models, which accounts for children having different slopes (e.g., not all children had the same rate of growth). To test which random-effects model to use we plot children's growth over time to determine if there is variation in slope. A fan-like pattern suggests a random-intercept and slope model should be used. We found considerable variation in slopes for individual growth determined that the use a random-intercept and slope model for the analysis was appropriate.

To examine the relationship between the food insecurity variable and the rate of change in growth an interaction term was created between time and the food insecurity variable. For food insecurity path, each model was run four times with each food insecurity path serving as the reference group. This allowed us to test differences in growth not just between food-insecure children and food-secure children but to examine differences across all food insecurity paths. The parameter estimates using food-secure children as the reference are presented but alphabetical letters note significant differences between the different food insecure paths.

Other interaction terms between potential risk factors and time were also explored. Three-way interactions were examined between food insecurity path and time and the following variables stress, family income trajectory, and sex. We used reverse backward elimination and removed non-significant variables one at a time until each variable retained in the model had a type-3 fixed effect p-value < 0.20. The amount of variation explained by each model was calculated using the percent difference in covariance parameters between the model with time as the only covariate compared to the full multivariate model. We also calculated descriptive statistics for all variables for the analysis sample presented in **Table 4.3**.

Table 4.3. Characteristics of analysis sample (n=517)

	No.	%
Food insecure during early pregnancy		
Food insecure	123	23.8
Food secure	394	76.2
Food insecure at age 2 years		
Food insecure	120	23.2
Food secure	397	76.8
Food insecurity path		
Stay food-insecure	55	10.6
Become food insecure	65	12.6
Move out of food insecurity	68	13.2
Never food insecure	329	63.6
Income Trajectory (0 to 2 years)		
Persistent	63	12.2
Unstable	155	30.0
Not low-income	299	47.8
Income trjaectory (0 to 14 years)		
Persistent low-income	57	11.0
Downwardly mobile	88	17.0
Upwardly mobile	78	15.1
Never low-income	294	56.9
Maternal overweight		
Overweight	254	49.1
Not overweight	263	50.9
Gestational weight gain		
Excessive	244	47.2
Inadequate	88	17.0
Adequate	185	35.8
Smoking during pregnancy		
Yes	103	19.9
No	414	80.1
Breasfeeding duration		
< 4 months	280	54.2
≥ 4 months	237	45.8
High-perceived stress		
Yes	160	31.0
No	357	69.0

Missing Data and multiple imputations

The small amount of missing data on early-life risk factors and controls were imputed using fully conditional specification imputation method for categorical and discrete variables in Proc Mi (22), which resulted in five imputed datasets. We used Proc Mianalyse to pool the outcomes from the five datasets. All analyses described were preformed with both the imputed datasets and a sample comprised of only children with no missing data. There were no significant differences in the results between the two samples. Therefore, in this article, the results are reported from the analyses of the imputed datasets.

RESULTS

Co-existing risk factors for obesity and food insecurity

Table 4.4 presents the adjusted odds ratios examining the associations between early-life risk factors and the three measures of food insecurity: 1) food insecurity path; 2) food insecurity before birth; and 3) food insecurity at 2 years. Generally, we found that children who experience food insecurity were more likely to experience social and biological risk factors for the development of overweight and obesity. When we examine the odds of being food insecure across the different models there is only one consistent risk factor: unstable low-income. Children who were unstable low-income were more likely to be grouped in the "stay", "become", and "move-out of" food insecurity paths, as well as experience food insecurity before birth and at age 2 compared to never low-income children. When we examine differences across food insecurity path there are two noteworthy findings. First, children who become food insecure were more likely to have a mother who was overweight (OR=2.59, CI= 1.373, 4.885) compared to children who were food secure. Also, children who become food insecure were less likely to have mothers who had excessive gestational weight gain (OR=0.472, CI=0.244, 0.913) compared to children who were food secure. We did not find these associations for children who stay food insecure or move out of food insecurity. Second, while lower maternal education is significantly associated with children who stay or become food insecure, children who move out of food insecurity are not significantly different from food-secure children when it comes to maternal education.

When we compare independently the odds of being food insecure at the two time points we see similar trends in lower maternal education and high-perceived maternal stress. Contrary to what we might expect, children whose mothers had excessive gestational weight gain were more likely to be food insecure before birth (OR=1.781, CI= 1.073, 2.990) compared to children whose mother had adequate gestational weight gain.

Table 4.4. Odds ratios of early-life risk factors for food insecurity paths

	Food insecurity path[a]						Food insecurity at one time point[b]			
	Stay		Become		Move out of		Before birth		2 years old	
	OR	CI	OR	CI	OR	CI	OR	CI	OR	CI
Income Trajectory (0 to 2 years)										
Persistent	**3.114**	**1.166, 8.320**	2.286	0.985, 5.305	1.369	0.536, 3.496	1.716	0.856, 3.437	**2.509**	**1.286, 4.893**
Unstable	**5.952**	**2.813, 12.594**	**4.087**	**2.105, 7.935**	**3.593**	**1.931, 6.686**	**3.141**	**1.917, 5.147**	**3.307**	**1.990, 5.497**
Not low-income	1	-	1	-	1	-	1	-		
Maternal overweight										
Overweight	1.064	0.537, 2.111	**2.59**	**1.373, 4.885**	1.513	0.835, 2.742	-	NS	1.498	0.951, 2.360
Not overweight	1	-	1	-	1	-				
Gestational weight gain										
Excessive	1.1356	0.630, 2.917	**0.472**	**0.244, 0.913**	1.514	0.758, 3.021	**1.781**	**1.073, 2.990**		NS
Inadequate	1.13	0.428, 2.982	0.464	0.188, 1.146	1.661	0.727, 3.794	1.676	0.865, 3.246		
Adequate	1	-	1	-	1	-	1	-		
Smoking during pregnancy										
Yes	**2.306**	**1.130, 4.706**	1.451	0.713, 2.952	**2.211**	**1.136, 4.301**	**2.177**	**1.304, 3.632**	1.566	0.932, 2.629
No	1	-	1	-	1	-				
Education category										
High school grad or less	**4.824**	**1.871, 12.436**	**2.641**	**1.206, 5.780**	1.879	0.930, 3.797	**2.171**	**1.223, 3.753**	**2.705**	**1.463, 5.002**
Some college or technical school	2.345	0.814, 6.756	**2.555**	**1.144, 5.708**	1.162	0.526, 2.564	1.257	0.659, 2.399	**2.357**	**1.221, 4.548**
College graduate or more	1	-	1	-	1	-				
High-perceived stress										
Yes	**2.994**	**1.48, 4.81**	**2.67**	**1.48, 4.81**	1.715	0.954, 3.086	**1.708**	**1.082, 2.697**	**2.435**	**1.542, 3.847**
No	Ref	-	Ref	-	Ref	-				

[a] Adjusted models provide the odds ratios of being in a certain food insecure path for the specified covariate after accounting for the other covariates in the model compared to food-secure children.

[b] Adjusted models provide the odds ratios of being in food insecure for the specified covariate after accounting for the other covariates in the model compared to food-secure children.

Backward elimination was used until all variables had a p-value <0.20. Eliminated variables for all models include: breastfeeding duration, maternal age, multiparious, and marital status

Signifcant p-values at <0.05 in **bold**

Change in growth and food insecurity status

Figure 4.1 illustrates the cross-sectional averages in BMI z-score from 0 to 15 years by food insecurity path. While BMI z-score rises in early childhood for all food insecurity paths and then plateaus in late childhood, there are descriptive differences in the magnitude of BMI z-score and when it begins to plateau. For example, children who become-food insecure have a rapid rise in BMI z-score until age 6 when it begins to level off, while food-secure children rise until about age 8, and then BMI z-score declines into late childhood.

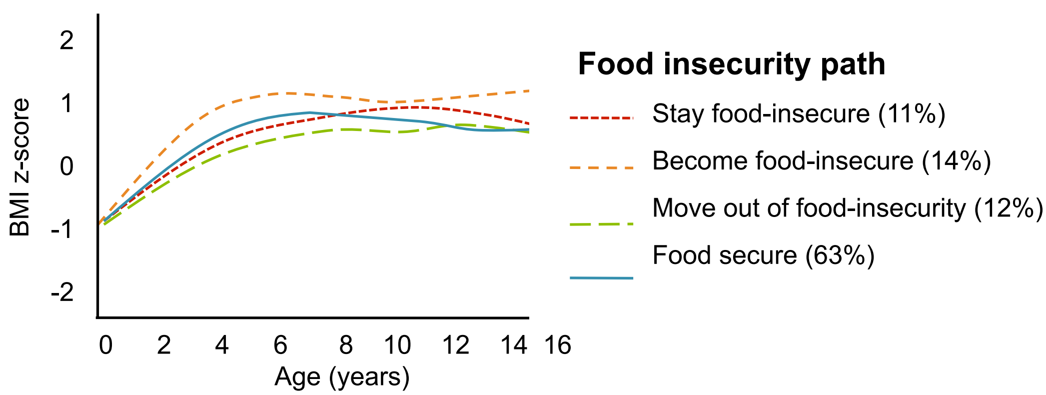


Figure 4.1. Cross-sectional differences in BMI z-score from 0 to 15 years by food insecurity path.

To examine if these differences remain after accounting for other risk factors and confounders we created linear mixed models that examined the change in WFL z-scores and BMI z-scores during infancy and childhood up to age 15 years. We compared food-insecure children to food-secure children to examine differences in three aspects of growth: 1) starting status of growth; 2) slope of growth; and 3) ending status of growth. We investigated the differences in growth between food-insecure children and food-secure children first with the measures of food insecurity at separate time points and then with the longitudinal measure of food insecurity.

Change in WFL z-score during infancy, 0 to <2 years

The estimated rate change in growth in infancy was positive for all groups, regardless of food-insecurity status. The estimated rate of growth in WFL z-score by a child's food insecurity status is illustrated in **Figure 4.2** and the parameter estimates are presented in **Table 4.5.** We found no significant associations between growth in infancy and food insecurity status before birth. We did find significant differences in the rates of growth during infancy among food insecurity paths. We found that children who move out of food insecurity have a significantly more gradual slope compared to all other groups (-0.2584 WFL z-score units per year, p=0.0374). In contrast, children who become food insecure have a significantly steeper slope compared to children who stay and move out of food insecurity (0.1077 WFL z-score units per year).

We also found associations between a positive rate change in WFL z-score and maternal overweight (0.2471 WFL z-score units per year, p=0.0021), while, inadequate gestational weight gain was associated with a negative rate change (-0.3926 WFL z-score units per year, p=0.003).

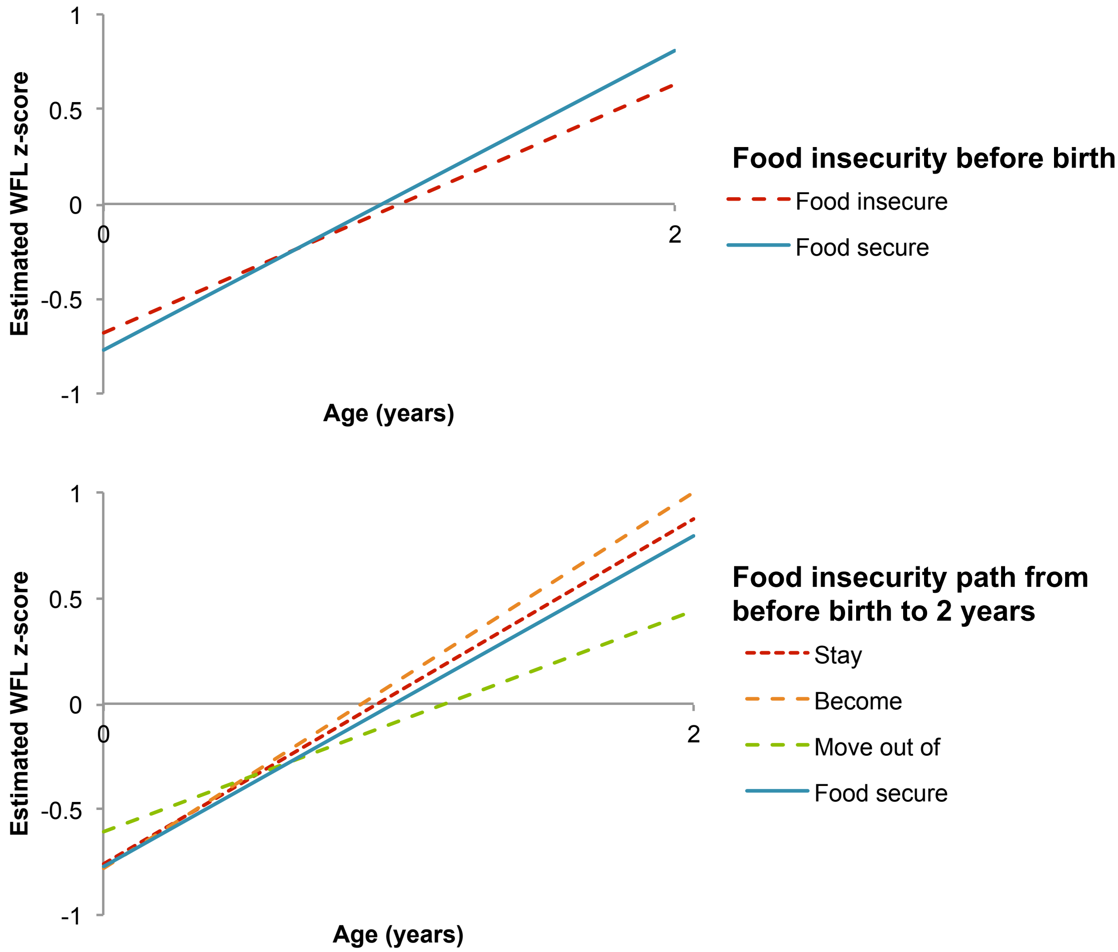


Figure 4.2. Changes in WFL z-score in infancy, 0 to 2 years, by food insecurity status

Table 4.5. Parameter estimates for change in WFL z-scores during infancy, 0 to 2 years, by food insecurity status

	Change in weight-for-length z-score (0 to 2 years)						
	n=517						
% variation explained by model for the:							
Intercept		9.0			9.2		
Slope		6.6			8.6		
	Estimate	**SE**	**p-value**	**Estimate**	**SE**	**p-value**	
Intercept	**-0.7702**	**0.2279**	**0.0008**	**-0.7705**	**0.2289**	**0.0008**	
Time	**0.7939**	**0.059**	**<0.0001**	**0.7818**	**0.06027**	**<0.0001**	
Food insecure during early pregnancy							
Food insecure	0.08876	0.1098	0.4191	-	-	-	
Food secure	Ref	-	-	-	-	-	
Food insecure during early pregnancy							
Food insecure X time	-0.1366	0.09513	0.1517	-	-	-	
Food secure X time	Ref	-	-	-	-	-	
Food insecurity path							
Stay food-insecure	-	-	-	0.0294	0.15	0.8447	a
Become food insecure	-	-	-	-0.01027	0.1437	0.9431	a
Move out of food insecurity	-	-	-	0.1611	0.1405	0.2523	a
Never food insecure	-	-	-	Ref	-	-	a
Food insecurity path X time							
Stay food-insecure X time	-	-	-	0.0378	0.1308	0.7727	a
Become food insecure X time	-	-	-	0.1077	0.1302	0.4085	b
Move out of food insecurity X time	-	-	-	**-0.2584**	**0.1237**	**0.0374**	c
Never food insecure X time	-	-	-	Ref	-	-	a
Income trajectory (0 to 2 years)							
Persistent low-income	0.01705	0.1186	0.8857	0.007913	0.1196	0.9473	
Unstable low-income	0.04929	0.09643	0.6092	0.03942	0.09832	0.6886	
Never low-income	Ref	-	-	Ref	-	-	
Maternal overweight							
Yes	**-0.1974**	**0.09136**	**0.0312**	**-0.198**	**0.0918**	**0.0315**	
No	Ref	-	-	Ref	-	-	
Maternal overweight X time							
Yes X time	**0.254**	**0.07983**	**0.0016**	**0.2471**	**0.0798**	**0.0021**	
No X time				Ref	-	-	
Gestational weight gain							
Excessive	-0.08749	0.08527	0.3054	0.08354	0.08565	0.3299	
Inadequate	**-0.3981**	**0.1075**	**0.0002**	**-0.3926**	**0.1081**	**0.003**	
Adequate	Ref	-	-	Ref	-	-	

[a]Control for maternal education, maternal age category, marital status, multiparious, and child sex

Signifcant p-values at <0.05 in **bold**

Different alphabetical letters next to food insecurity path variables note significant differences between different groups at p-values <0.05

Change in BMI z-score during childhood, 2 to 15 years

Figure 4.3 illustrates the estimated rates of growth during childhood from 2 to 15 years by a child's food insecurity status. Three differences in growth among children by food insecurity status were found corresponding to time: 1) beginning BMI z-score—at age 2; 2) rate of change in BMI z-score; and 3) ending BMI z-score—at age 15). First, food-insecure children have lower estimated BMI z-scores compared to food-secure children at the beginning of childhood, age 2. Second, food-insecure children have increased growth rates during childhood, while food-secure children have fairly stable growth. Finally, food-insecure children have elevated estimated BMI z-scores compared to food-secure children at the age 15.

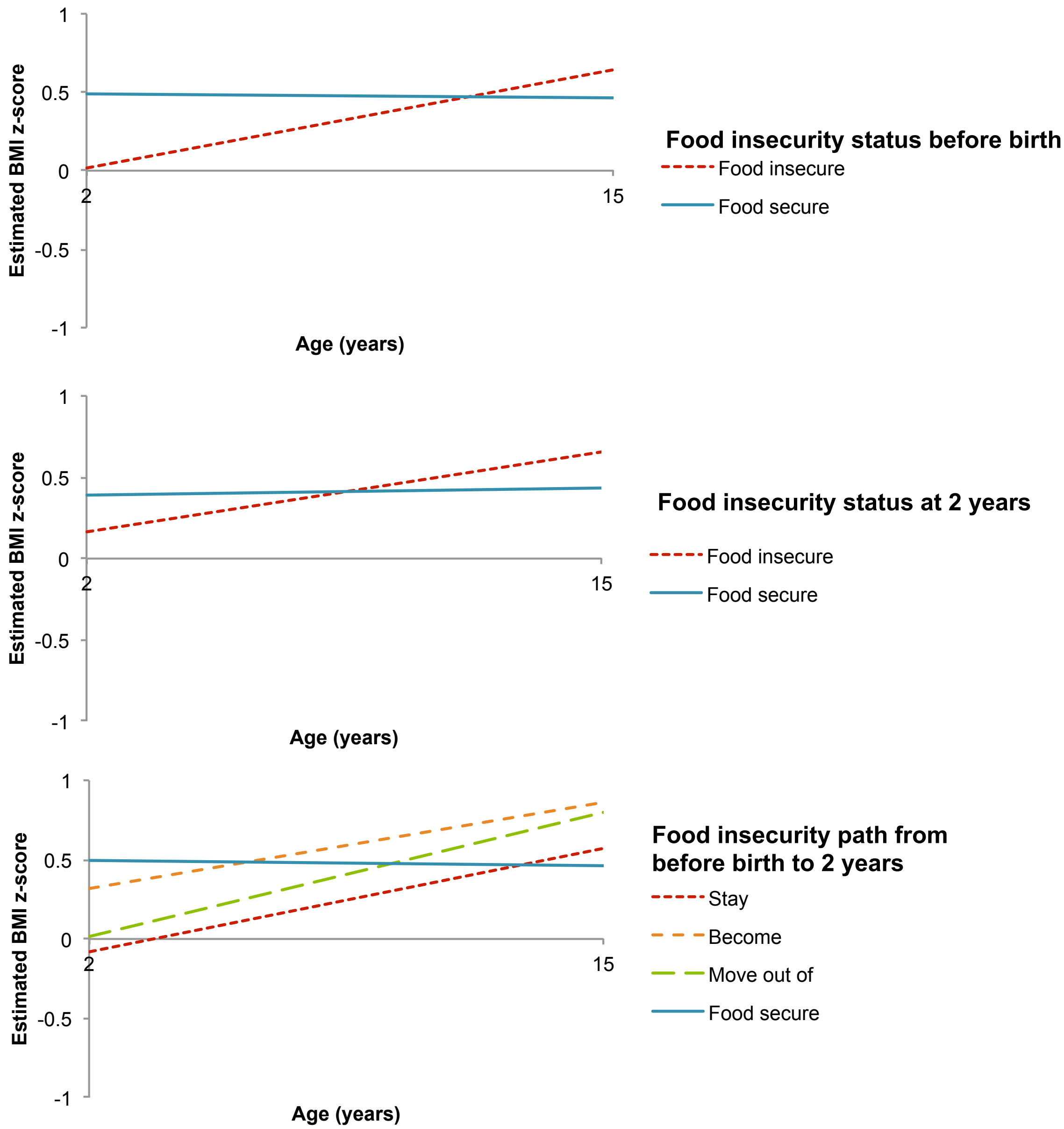


Figure 4.3. Change in BMI z-score during childhood, 2 to 15 years, by food insecurity status

There are two key differences in growth among children depending on the measure of food insecurity status that should be highlighted from the parameter estimates presented in **Table 4.6**. First, children who are food-insecure before birth have lower BMI z-score at the start of childhood (-.5707 BMI z-score units, $p<0.0001$) but surpass food-secure children by late childhood (at a rate of 0.04989 BMI z-score units per year, $p<0.0001$). This is also reflected in the growth of children in the two food insecure paths that start off food-insecure, "stay" and "move out of" food insecurity. Second, children who are food insecure at age 2 also begin childhood smaller compared to food-secure children (-0.2944 BMI z-score units, $p=0.0274$) they are larger compared to children who were food-insecure before birth. Finally, while children in the food-insecure paths (stay, become, move out of food insecurity) had significantly different aspects of growth compared to children who were food-secure, there were no significant differences in growth among children who stay, become, or move out of food insecurity.

In addition, we found two associations between growth and early-life risk factors. First, children whose mothers were overweight had a positive estimated rate change in BMI z-score (0.03121 BMI z-score units per year, $p=0.0034$). Second, early-life growth was also strongly associated with growth in childhood. Children who had high-rising trajectories in infancy had elevated estimated BMI z-scores of about 0.7 BMI z-score units compared to children who had stable trajectories in infancy. While children who had low-rising trajectories had lower estimated BMI z-scores of about 0.5 BMI z-score units compared to the children who had stable trajectories in infancy. Our data did not support significant associations between BMI z-score in childhood and gestational weight, maternal smoking, high-perceived stress, or breastfeeding duration. In addition, none of the interactions between food insecurity and sex, family income trajectory, or stress, were significant.

Table 4.6. Parameter estimates for change in BMI z-scores during childhood, 2 to 15 years, by food insecurity status

	Change in BMI z-score (2 to 15 years)									
	n=517									
% variation explained by model for the:	**Food insecurity during pregnancy**			**Food insecurity at 2 years**			**Food insecurity path**			
Intercept	32.7			30.7			33.0			
Slope	12.7			11.9			13.7			
	Estimate	**SE**	**p-value**	**Estimate**	**SE**	**p-value**	**Estimate**	**SE**	**p-value**	
Intercept	0.4917	0.2658	0.065	0.3834	0.268	0.1533	0.4931	0.2572	0.0558	
Time	-0.002	0.0117	0.8537	0.0116	0.7734	0.8537	-287	0.0126	0.8198	
Food insecure during early pregnancy										
Food insecure	**-0.571**	**0.1277**	**<0.0001**	-	-	-	-	-	-	
Food secure	Ref	-	-	-	-	-	-	-	-	
Food insecure during early pregnancy										
Food insecure X time	**0.0499**	**0.0124**	**<0.0001**	-	-	-	-	-	-	
Food secure X time	Ref	-	-	-	-	-	-	-	-	
Food insecure at age 2 years										
Food insecure	-	-	-	**-0.294**	**0.1331**	**0.0274**	-	-	-	
Food secure	-	-	-	Ref	-	-	-	-	-	
Food insecure at age 2 years										
Food insecure X time	-	-	-	**0.0344**	**0.0128**	**0.0075**	-	-	-	
Food secure X time	-	-	-	Ref	-	-	-	-	-	
Food insecurity path										
Stay food-insecure	-	-	-	-	-	-	**-0.675**	**0.2000**	**0.0008**	a
Become food insecure	-	-	-	-	-	-	-0.259	0.1861	0.1646	ab
Move out of food insecurity	-	-	-	-	-	-	**-0.599**	**0.176**	**0.0007**	a
Never food insecure	-	-	-	-	-	-	Ref	-		b
Food insecurity path X time										
Stay food-insecure X time	-	-	-	-	-	-	**0.0527**	**0.0192**	**0.0063**	a
Become food insecure X time	-	-	-	-	-	-	**0.0438**	**0.0178**	**0.0141**	a
Move out of food insecurity X time	-	-	-	-	-	-	**0.0627**	**0.0168**	**0.0002**	a
Never food insecure X time	-	-	-	-	-	-	Ref	-		b
Income trjaectory (0 to 14 years)										
Persistent low-income	0.1119	0.179	0.5324	0.0298	0.1810	0.8693	0.1537	0.1944	0.4295	
Downwardly mobile	0.1328	0.1405	0.3453	0.1161	0.1400	0.4205	0.1606	0.1558	0.3032	
Upwardly mobile	0.1304	0.1669	0.4350	0.1271	0.1718	0.4598	0.1863	0.1860	0.3172	
Never low-income	Ref	-	-	Ref	-	-	Ref	-	-	
Income trjaectory (0 to 14 years) x time										
Persistent low-income X time	-0.031	0.0165	0.0630	-0.022	0.0164	0.1842	**-0.037**	**0.0181**	**0.0426**	
Downwardly mobile X time	-0.004	0.0133	0.7557	-0.003	0.0135	0.9284	-0.009	0.0147	0.5505	
Upwardly mobile X time	-0.017	0.016	0.2767	-0.016	0.0163	0.3125	-0.029	0.0179	0.1053	
Never low-income X time	Ref	-	-	Ref	-	-	Ref	-	-	
Maternal overweight										
Yes	**0.3036**	**0.1045**	**0.0038**	**0.2926**	**0.1590**	**0.0059**	**0.3115**	**0.1141**	**0.0066**	
No	Ref	-	-	Ref	-	-				
Maternal overweight X time										
Yes X time	**0.0353**	**0.0101**	**0.0005**	**0.0352**	**0.0101**	**0.0006**	**0.0312**	**0.0109**	**0.0034**	
No X time	Ref	-	-	Ref	-	-	Ref	-	-	
Gestational weight gain										
Excessive	-	-	NS	-	-	NS	-	-	NS	
Inadequate	-	-	-	-	-	-	-	-	-	
Adequate	-	-	-	-	-	-	-	-	-	
Early-life growth trajectory										
High-rising	**0.6461**	**0.1338**	**<0.0001**	**0.6908**	**0.1355**	**<0.0001**	**0.6520**	**0.1468**	**<0.0001**	
Low-rising	**-0.538**	**0.1303**	**<0.0001**	**-0.501**	**0.1320**	**0.002**	**-0.527**	**0.1434**	**0.0003**	
Stable	Ref	-	-	Ref	-	-	Ref	-	-	
Early-life growth trajectory X time										
High-rising X time	-0.019	0.0133	0.1465	-0.023	0.0134	0.0847	-0.019	0.0144	0.1890	
Low-rising X time	0.0185	0.0131	0.1593	0.0148	0.0132	0.2622	0.0157	0.0142	0.2700	
Stable X time	Ref	-	-	Ref	-	-	Ref	-	-	

[b] Control for maternal education, maternal age category, marital status, multiparious, child sex, child medicaiton use (ADHD, asthma, and antidepressants), child start of puberty

Signifcant p-values at <0.05 in **bold**

Different alphabetical letters next to food insecurity path variables note significant differences between different groups at p-values <0.05

DISCUSSION

Previous longitudinal studies have not found significant relationships between food insecurity and changes in growth early childhood. We make three noteworthy contributions that extend our understanding of whether food insecurity impacts growth. First, many biological and social risk factors were associated a child being food insecure. Children who move in and out of low-income were more likely to experience food insecurity at any time point compared to other income groups. Other risk factors associated with food insecurity varied by the timing of food insecurity. Interestingly, mothers who had excessive gestational weight gain were more likely to be food insecure. This highlights the paradoxical association between weight gain and food insecurity in these women, which has been previous examined by Olson and colleagues (17). We also found that lower maternal education was associated with “stay” and “become” food insecure but “not move out of” food insecurity. The clustering of early-life risk factors demonstrates the disproportionate risk many food-insecure children carry and the challenge for researchers to try to isolate those effects. One way to address the clustering of risk factors is to examine the impact of changes in food insecurity status on growth.

Our second contribution was to examine the longitudinal association between food insecurity path, before birth to 2 years, and growth in infancy, 0 to 2 years. When “stay” and “become food-insecure” children were compared to food-secure children there are no differences in growth. When “stay” and “become” food-insecure children were compared to children who “move out of” food insecurity they have significantly steeper slopes of growth. Jyoti and colleagues (7) made similar comparisons with “move out of” food insecurity as a reference group, but found no significant differences in change in BMI z-score. Our findings in infancy could differ for two reasons. One, we modeled the rate of change, not simply the overall change in BMI z-score. Two, we examined changes in growth during infancy while Jyoti and collegues used the kindergarten to 3rd grade sample.

In general, our results do not suggest a strong association between food insecurity and rates of growth in infancy. It is possible that the potential biological, behavioral, and environmental mechanisms that link food insecurity to growth are not apparent in infancy. We hypothesize that food insecurity is related to growth by a similar mechanism to the fetal origins hypothesis (23). Initially, food-insecure children are smaller compared to food-secure children. However, their rates of growth are greater due to potential biological, behavioral, and environmental mechanisms, which result in an overall higher level of growth later in life.

Our third contribution was to look beyond infancy and early childhood to the rate of growth up to age 15. The potentially protective effect of "moving out of" food-insecurity in infancy disappeared and the risks of any early food insecurity appeared. In childhood, all food-insecure paths have positive slopes compared to the relatively stable growth of food-secure children. By age 15 all of the food-insecure paths had higher estimated BMI z-scores compared to the food-secure children. The higher estimated BMI z-scores in food-insecure children does not occur until later in childhood, which may explain why previous longitudinal studies have not found an association between food insecurity and growth.

We made three important methodological choices that improve our understanding of whether food insecurity impacts childhood growth. First, two developmental stages were examined infancy and childhood up to age 15, while previous longitudinal studies had only examined infancy and early childhood. Second, a longitudinal measure of food insecurity was used allowing the examination in changes in food insecurity related to growth. Third, we modeled the rate change in growth, allowing us to examine other aspects of growth rather than the overall difference.

The findings of this study should also be considered in the context of the study's limitations. These limitations also provide directions for future research. First, the measures of food insecurity are only up to 2 years of age. Future work that examines how movements in and out of food insecurity across childhood alter rates of growth is warranted. Second, the sample has higher rates of food insecurity and overweight and obesity compared to national averages. Future work in more diverse and representative samples is needed to verify the findings. Third, we do not have measures of dietary intake or physical activity, which would allow us to test casual pathway connecting food insecurity and rates of growth. Finally, due to changes in measures of food insecurity during the time of the study food insecurity was measured differently at each time period and was assessed using only 3 questions. Food insecurity is now measured by the USDA based on the responses of 3 to 18 questions in the Core Food Security Module (24).

Conclusions

In this longitudinal study from birth to 15 years of age, we provide new evidence to suggest that children who experience food insecurity early in life have steeper rates of growth compared to children who do not experience food insecurity. These findings provide new insight into why previous longitudinal studies in early childhood have been inconclusive and support the need for future research to investigate the mechanisms that trigger increased rates of growth in food-insecure children during childhood.

REFERENCES

1. Coleman-Jensen A, Nord M, Carlson S. Household food security in the United States in 2010. 2011 Sep p. 37. Report No.: ERR-125.

2. Ludwig DS, Pollack HA. Obesity and the economy: from crisis to opportunity. JAMA. 2009 Feb 4;301(5):533–5.

3. Drewnowski A, Specter SE. Poverty and obesity: the role of energy density and energy costs. Am. J. Clin. Nutr. 2004 Jan;79(1):6–16.

4. Hartline-Grafton HL, Rose D, Johnson CC, Rice JC, Webber LS. Energy density of foods, but not beverages, is positively associated with body mass index in adult women. Eur J Clin Nutr. 2009 Dec;63(12):1411–8.

5. Rolls BJ. The relationship between dietary energy density and energy intake. Physiol. Behav. 2009 Jul 14;97(5):609–15.

6. Frongillo EA, Rowe EM. Challenges and solutions using and analyzing longitudinal growth data. In: Johnston F, Eveleth P, Zemel B, editors. Human Growth in Context. London, UK: Smith-Gordon; 1999. p. 41–64.

7. Jyoti DF, Frongillo EA, Jones SJ. Food insecurity affects school children's academic performance, weight gain, and social skills. J. Nutr. 2005 Dec;135(12):2831–9.

8. Bhargava A, Jolliffe D, Howard LL. Socio-economic, behavioural and environmental factors predicted body weights and household food insecurity scores in the Early Childhood Longitudinal Study-Kindergarten. Br. J. Nutr. 2008 Aug;100(2):438–44.

9. Rose D, Bodor JN. Household food insecurity and overweight status in young school children: results from the Early Childhood Longitudinal Study. Pediatrics. 2006 Feb;117(2):464–73.

10. Winicki J, Jemison K. Food Insecurity and Hunger in the Kindergarten Classroom: Its Effect on Learning and Growth. Contemporary Economic Policy. 2003;21(2):145–57.

11. Bronte-Tinkew J, Zaslow M, Capps R, Horowitz A, McNamara M. Food insecurity works through depression, parenting, and infant feeding to influence overweight and health in toddlers. J. Nutr. 2007 Sep;137(9):2160–5.

12. Larson NI, Story MT. Food Insecurity and Weight Status Among U.S. Children and Families: A Review of the Literature. American Journal of Preventive Medicine. 2011 Feb;40(2):166–73.

13. Ong KK, Loos RJF. Rapid infancy weight gain and subsequent obesity: systematic reviews and hopeful suggestions. Acta Paediatr. 2006 Aug;95(8):904–8.

14. WHO | WHO Child Growth Standards: Methods and development [Internet]. WHO. [cited 2012 Jun 18]. Available from: http://www.who.int/childgrowth/publications/technical_report_velocity/en/index.html

15. Institute of Medicine. Nutrition during pregnancy and lactation. An implementation guide. Washington, DC: National Academy Press; 1992.

16. Bickel G, Nord M, Price C, Hamilton W, Cook J. Guide to measuring household food security. Alexandria, VA: Food and Nutrition Service, US Department of Agriculture; 2000.

17. Olson CM, Strawderman MS. The relationship between food insecurity and obesity in rural childbearing women. J Rural Health. 2008;24(1):60–6.

18. Graham JW. Missing Data Analysis: Making It Work in the Real World. Psychology. 2009 Jan;60(1):549–76.

19. Jones BL, Nagin DS, Roeder K. A SAS Procedure Based on Mixture Models for Estimating Developmental Trajectories. Sociological Methods & Research,. 2001 Feb 1;374 –393 vol. 29:

20. Nagin DS. Group-Based Modeling of Development. Harvard University Press; 2005.

21. Weight Gain During Pregnancy: Reexamining the Guidelines [Internet]. [cited 2012 Jun 17]. Available from: http://www.nap.edu/openbook.php?record_id=12584&page=1

22. Buuren S van. Multiple imputation of discrete and continuous data by fully conditional specification. Stat Methods Med Res. 2007 Jun 1;16(3):219–42.

23. Oken E, Gillman MW. Fetal origins of obesity. Obes. Res. 2003 Apr;11(4):496–506.

24. USDA Economic Research Service - Survey Tools [Internet]. [cited 2012 Aug 6]. Available from: http://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/survey-tools.aspx

CHAPTER 5

Associations between the rural middle school nutrition and physical activity environment, family income trajectory, and change in BMI z-scores during adolescence

ABSTRACT

Introduction: Rural and low-income adolescents are a vulnerable population at increased risk for obesity. The goal of this study was to test whether family income trajectory moderates the association between the middle school nutrition and physical activity (N&PA) environment and change in body mass index (BMI) z-score during adolescence.

Methods: The individual-level sample for this study was a rural, upstate New York State birth cohort, grades 6^{th} through 8th (n=281). The middle school N&PA environment was assessed using questionnaires for the principal, food service director, and head PE teacher, along with a researcher completed checklist at 17 schools. The environment was summarized by six issue-specific scores capturing: school meal quality and availability, food fundraising policies, general healthy eating promotion, quality of physical education, sports offerings and participation, and general physical activity promotion. Measured heights and weights wered used to determine BMI z-score and family income trajectory was derived using latent-class modeling.

Results: Although there was not a direct association between the school environment scores and change in BMI z-score during middle school, the association between school environment scores and change in BMI z-score depended on an adolescent's family income trajectory. Specifically, among adolescents with either unstable or persistent low-income trajectories reductions in BMI z-scores were associated occurred among those in middle schools with better physical activity environments.

Discussion: Our multidimensional assessment of the school environment reveals heterogeneity within and between schools, suggesting that solutions to address childhood obesity through the school environment will not be one-size-fits-all. Our findings highlight the potential role of the middle school physical activity environment in reducing BMI during middle school for certain income groups.

INTRODUCTION

Rural children are less physically active and more at risk for overweight and obesity than their metropolitan counterparts (1–3). This relation remains even after accounting for disparities in income and access to healthcare, suggesting that the rural environment is more obesogenic. There is growing evidence and consensus in the scientific community that an obesogenic environment is a significant, if not the primary, cause of increasing obesity rates (4). Obesogenic environments promote obesogenic behaviors such as unhealthy eating and limited physical activity. Therefore, decisions that impact how environments are created or used are critical for reducing obesogenic behaviors. Schools are opportune settings for interventions to address obesity as children spend approximately half of their waking hours in school. Schools provide 1 to 2 meals daily and often the only structured physical activity opportunity made available to a child.

For rural adolescents, schools may be one of the few places policy or environmental interventions could impact them outside of the home (5). Middle schools support the development of behaviors in adolescents that will carry on into adulthood and thus middle schools have the chance to play a critical role in adult obesity prevention. Adolescent physical activity declines rapidly from ages 9 to 15 (6), which provides the middle school environment an opportunity to maintain physical activity in adolescents. In a national survey only 7.9 percent of middle schools provided daily PE to students (7). On the other side of the energy balance equation, school environments are recognized as having an influence on students' eating behaviors (8,9). In a nationally-representative sample, findings suggest the frequency of fruit and vegetable provisions, food availability in vending machines, other competitive food outlets, and start of school time are all policy avenues that may be leveraged to affect students' growth and food consumption (10).

Despite the growing consensus that the environment influences nutrition and physical activity behavior, the science of measuring and evaluating this relationship is still in its infancy (11). Current methods for assessing the school environment are often conducted with a particular focus on one aspect of the environment, such as competitive food availability. In addition, previous studies on the school environment have focused heavily on self-reported data from students and administrators with no objective measures of the environment or input from key people who control selected aspects of the school environment. Several recently published reviews on the impact of the environment on childhood obesity revealed the following critical areas for future research: examining populations that are rural and vary in income, using longitudinal rather than cross-sectional data, and combining physical activity and nutrition variables (12–14).

To address these gaps, we employ a rural, upstate New York State birth cohort to investigate the links between income trajectories from birth to adolescence, the school nutrition and physical activity (N&PA) environment, and measured body mass index (BMI) z-score during middle school, grades 6 through 8. This study is guided by the bio-ecological systems theory (BEST) (5), which highlights the need to consider contextual influences on childhood obesity.

In BEST, biological, behavioral, and environmental components are intertwined, and none can be fully considered without understanding the systems in which they are embedded (15). There are three primary levels within BEST. First, the micro-level represents the biological risk of the individual. In the cohort we include important biological and social risk factors previously associated with childhood BMI. Second, the meso-level refers to connections between contexts, for example, the interaction between the individual's biological risk and their school environment. We developed an assessment tool to distinguish school environments that promote healthy eating and physical activity from environments that do not. Third, the macro-level is comprised of the effects of culture, society, and economics that have a cascading influence throughout the interactions of all other layers. In this study, we represent the macro-level with an adolescent's socioeconomic status (SES), which we capture by using an adolescent's family income trajectory. Including an adolescent's family income trajectory in our conceptual framework is important because solutions are not one-size fits all. To our knowledge, this is the first study to examine the association between multidimensional measures of the school environment and BMI z-score considering an individual's socioeconomic status as a potential modifier.

The objectives of this study were three-fold. First, to characterized the school N&PA environment with a multidimensional assessment. Second, to examine the association between the school environment and BMI z-score during middle school. Third, to examine if family income trajectory modifies the relationship between the school environment and BMI z-score during middle school. We hypothesized that better middle school environment reduce the BMI z-scores of adolescents with poorer income trajectories the most.

METHODS

Design

A longitudinal design was used to study the association between the school N&PA environment, family income trajectory, and adolescent BMI z-score in rural, upstate New York State. Individual-level data were obtained from a population-based birth cohort whose mothers enrolled in the Bassett Mothers Health Project 1 (BMHP1) (16). General health and growth data were obtained through a retrospective audit of their medical charts, completed in August 2011. School-level data were collected from a contemporary assessment of 17 middle school N&PA environments using questionnaires for the principal, food service director, head PE teacher, and an observational checklist, completed in June 2011.

Sample

At the individual-level, the original population-based sample was comprised of 595 full-term, singlet children, born from June 1995 to July 1997. The sample was comprised of primarily white (96%), rural, and socioeconomically diverse adolescents. These adolescents live in an 8-county region of rural, upstate New York State. We define rural at the county level as having a population less than 200,000 with no town or city with a population of 20,000 people or more. Of the original sample there were 380 adolescents who had a BMI measurement during their middle school years. After accounting for attrition and the selection criteria for school assessment (at least 5 adolescents from the cohort attend the school), the analysis sample was comprised of 281 adolescents. The characteristics of the original population-based sample and the analysis sample are shown in **Table 5.1**. Chi-square analyses were conducted to compare adolescents included in the analysis sample to those not included, in order to identify any factors that might be different. There was a higher proportion of boys in the analysis sample compared to the loss to follow-up sample. There was also a smaller proportion of adolescents with low-rising growth trajectories, a control variable characterized by being small at birth with rising weight-for-length z-score status to age 2, in the analysis sample compared to the loss to follow-up sample. All other variables used in the analysis do not differ significantly across the samples and thus the analysis sample remains a reasonable one to explore our hypotheses.

Table 5.1. Characteristics of population sample (n=595), middle school sample (n=380), and analysis sample (n=281)

	Population Sample		Middle School Sample			Analysis Sample		
	n=595		n=380			n=281		
Characteristic	No.	%	No.	%	p-value[a]	No.	%	p-value[b]
Maternal overweight/obese					**0.54**			**0.66**
Yes	295	50%	216	58%		161	57%	
No	300	50%	160	43%		120	43%	
Low-income at birth					**0.12**			**0.75**
Yes	258	43%	154	41%		120	43%	
No	337	57%	222	59%		161	57%	
Early-life growth trajectories*					**<0.0001**			**<0.0001**
High rising	179	30%	139	37%		105	37%	
Low rising	293	49%	152	40%		105	37%	
Stable	123	21%	85	23%		71	25%	
Sex					**0.05**			**0.015**
Male	317	53%	189	50%		131	47%	
Female	278	47%	187	50%		150	53%	
Start of puberty								**0.63**
After middle school			66	17%		47	17%	
Before middle school			78	21%		61	22%	
During middle school			232	62%		173	61%	
Income trajectory								**0.18**
Persistent low-income			78	21%		62	22%	
Unstable low-income			69	18%		55	20%	
Never low-income			228	61%		162	58%	
Missing			5			2		
Current ADHD medication use								**0.59**
Yes			37	10%		29	10%	
No			339	90%		252	90%	

[a] Chi-squared analysis p-value comparing middle school cohort to those not included from the population sample.

[b] Chi-squared analysis p-value comparing analysis sample to those not included from the population sample, except the adolescent characteristics which were compared to those not included from the middle school cohort (puberty status, income trajectory, and current ADHD medication use).

* Early life growth trajectories are latent class groups based on the adolescents weight-for-legnth growth from 0 to 24 months.

At the school-level, there were 51 schools in the region that the adolescents in the sample attended. We used the adolescents' medical records to determine which school they attended. There were 50 adolescents who did not have a school recorded with their measurements. For these adolescents, we used their most current address to determine which school district they resided in and the closest middle school to their home. All school districts had only one public middle school (17). It is possible that these children attended other schools, however, since these were rural areas with significant distances between schools this is unlikely. Adolescents who were homeschooled were excluded from the middle school cohort (n=5). The range in number of students per school was 1 to 40. The only exclusion criterion for the school assessments was having fewer than 5 students from the cohort attending the school. Schools that were excluded were more likely to be at the periphery of the area served by the Bassett Healthcare. For example there were children who went for medical examinations at Bassett clinic in one county but attended middle school in another county not served by Bassett. After the exclusion criterion was applied there were 19 schools that were eligible for the school assessment.

All 19 schools were contacted first via an email that outlined the purpose of the study and the time required to participate. Schools that did not respond were then contacted via phone until the principal was reached. All 19 schools participated in some aspect of the study. The analysis sample consisted of the 17 schools (89%) that had complete data from all three respondents: principal, food service director, and PE teacher. One school was missing the principal survey and another school had been closed in the process of the evaluation due to a natural disaster.

School nutrition and physical activity environment

Tool development

The goal of the middle school N&PA environment assessment tool was to distinguish school environments that promote healthy eating and physical activity from environments that do not. The assessment tool draws heavily from the School Health Policies and Programs Study questionnaire (18) conducted by the CDC and the Eat Well Be Active questionnaire that was conceived from the ANGELO framework (19). The ANGELO framework is a model for understanding an environment's obesogenicity and suggests that the environment be divided into four parts: 1) physical: what is available; 2) economic: what are the costs; 3) political: what are the rules; and 4) socio-cultural: what are the attitudes and beliefs of the environment's inhabitants. Along with the literature review, we visited two non-study middle schools to observe the school environment and talk with the principals, PE teachers, kitchen staff, and students about what factors they believe impact students' eating and physical activity. These informal meetings were informative in the identification of the types of environmental factors that we wanted our tool to capture.

To better understand the relationship between environment and health-promoting behaviors we split the environment into concrete elements that were amenable to measurement. First, we distinguished six issue-specific aspects of the environment that we wished to capture: 1) school meal quality and availability; 2) food fundraising policies; 3) general healthy eating promotion; 4) quality of physical education; 5) sport offerings and participation; and 6) general physical activity promotion. Then we employed the ANGELO framework (19) and divided each issues-specific aspect of the environment into four types: physical, economic, political, and socio-cultural. A general description of each issue-specific score is shown in **Table 5.2**. Survey questions and researcher observation were used to capture each of these environment types within each issue-specific aspect of the school environment.

Table 5.2. Description of school issue-specific environment scores

Issue-specific score	No. of items	No. of items after testing reliability	Description of dimensions of score
School meal quality and availability	112	106	Number of meals offered, types of foods offered, quality of facilities used to prepare and served foods, who makes decisions about what food is offered, facilitators and barriers to providing healthier options, and the general attitudes and beliefs regarding the role of the food service at the school
Food fundrasing policies	16	15	Frequency of fundraising involving food, rules regulating the placement and nutritional content of food, and role of fundraising in schools to support school activities
General healthy eating promotion	14	13	Advertising for food/drinks, vending machines (placement, use of funds, rules of use), practices to improve healthy eating, and attitudes and beliefs of teachers and staff regarding healthy food promotion
Quality of physical education	21	21	Facilities for PE, number of teachers, number and type of activities, perceived limitations, quantity of time spent being physical active during PE, and facilitators and barriers to improving PE
Sports offerings and participation	6	6	Facilities for sports/clubs, number of coaches, availability of late bus, cost of sports teams/clubs, incentives for coaches, % participation by sex, and priority of sports/clubs within the school
General physical activity promotion	39	39	of physical activity as punishment, use of facilities outside of sports/PE, and attitudes and beliefs regarding the role of physical activity in school

The tool was then tested in two additional pilot middle schools that were not part of the original study but that shared similar demographics as the schools in the study. The tool was further revised based on feedback from personnel at the two pilot schools. The most significant changes occurred within the principal survey. Principals requested we shorten and condense questions to reduce the respondent burden. The finalized tool was comprised of three surveys, one each for the principal, food service director, and PE teacher, and one researcher observation checklist.

Score Creation

Each question or observation was coded to capture if the environmental characteristic, policy or action was health promoting. Either 1 or 0 was assigned to each dichotomous variable (yes or no). For answers that were not dichotomous, the distribution of answers was examined and coded based on being above or below the median. All the socio-cultural environment questions were originally answered based on a five-point scale (e.g., strongly agree, agree, neutral, disagree, strongly disagree), and these questions were summarized to a three-point scale based on the distribution of answers with an attempt to create a normal distribution. Variables were excluded from analysis if there was: little variation (62 variables) and missing for more than 25% of the schools (4 variables). After exclusion, there were 208 variables remaining to create environment scores. All the variables within an issue-specific aspect of the environment were summed to create the issue-specific score, with higher scores indicating a healthier school environment.

Family income trajectory

Adolescents' income trajectories were classified based on their family's movement in and out of low-income through childhood. Income was based on insurance codes recorded at the time of a child's medical visits. A child was classified low-income if their insurance was listed as Medicaid or Child Health Plus, which require families be below 185% of the poverty line. In the sample 81% of the adolescents had at least one income measurement every five years. The mean number of income measurements per adolescent in the sample was 16 (8 SD). Family income trajectory was derived from maximum-likelihood, longitudinal, latent-class modeling techniques in SAS 9.3 using PROC TRAJ (20,21). This group-based modeling strategy determines the probability of children's low-income over time and simultaneously considers timing, duration, and sequencing. *Family income trajectory* is a categorical variable with three groups: (1) never low-income; (2) unstable low-income; and (3) persistent low-income.

BMI z-score

BMI z-score is a continuous variable calculated based on the heights, weights, age, and sex recorded in the medical records. World Health Organization 2007 growth standards were used to calculate BMI z-scores (22). All BMI z-score values were graphically represented for each adolescent and checked visually for abnormalities. Any abnormalities were flagged and checked in the medical records for accuracy. The BMI measurements were opportunistically captured when a child went to a clinic served by the Bassett Healthcare Network. Therefore, measurement frequency and timing was different for each adolescent. Since the cohort recruitment period spanned two years and three grade levels, the analysis sample was divided into school year cohorts. There were no significant differences between school year cohorts. Measurements were included in analysis if they occurred between the summer prior to middle school and the summer following middle school. The average number of BMI z-score measures per adolescent in the sample was 3.4 (SD 1.9).

Statistical analysis

Characterization of school nutrition and physical activity environment

Descriptive statistics were calculated for the issue-specific score (e.g. mean, standard deviation, range, skewness, and Kurtosis) and two tests for construct validity: 1) Cronbach alphas and 2) mean inter-item correlation. Cronbach alphas capture the degree to which the items that comprises the score are intercorrelated. Cronbach alphas are often used to determine the overall degree to which the items that form the score are intercorrelated. Mean inter-item correlation indicates whether the scale items assess a single factor. The issue-specific scores measure broad and multidimensional aspects of the environment and we expect them to have low Cronbach alphas and a low mean inter-item correlation (23,24). We followed the recommendations of Clark and Watson (23), which suggest that individual inter-item correlations should be moderate in magnitude and should cluster narrowly around a mean value. We visually inspected the individual inter-item correlations for all 208 variables to assess deviations from the mean. We removed 8 variables that had outlying inter-item correlations, which left us with 200 variables comprising the six issue-specific scores.

For descriptive purposes the school N&PA issue specific-scores were standardized based on the total possible points within each issue-specific N&PA score. These standardized scores were used to compare the schools preformed across the issue-specific N&PA scores. In the hypothesis testing models, scores were not standardized.

Associations between family income trajectory, issue-specific scores and BMI z-score

We used linear mixed models with fixed and random effects to evaluate the association between adolescent BMI z-scores and school issue-specific environment scores. By including the school in the model as a random effect, this statistical method accounts for the additional component of variance anticipated when a cluster sampling design is employed and observations from subjects are likely to be correlated. In addition, we are able to evaluate whether the rate change (slope) in BMI z-score during middle school differed by family income trajectory and issue-specific score.

We conducted our hypothesis testing in two stages. First, we created a multivariate model including all issue-specific scores adjusting for potential confounders. Following the recommendations of Bryk and Raudenbush (25) we center all school environment scores at the sample mean. Next, we tested whether family income trajectory moderated the association between the issue-specific scores and BMI z-score during middle school. All models started with the following school-level confounders: percentage of students at the school who receive free and reduced priced meals as a proxy for school socioeconomic status, type of school captured by the number of grades in building (K through 12th, K through 8th, and 6th through 12th), the enrollment summarized into tertiles (<435 students, 435 to <754 students, and $\geq$ 754 students), and rurality based on National Center for Educational Statistics codes (26) (town, rural/distant, and rural/remote). Individual-level confounders were included to account for difference in growth during adolescence due to sex (male/female), puberty (early, late, and average), and current ADHD medication use (yes/no). There was very little missing data for individual level characteristics in this sample (<5%). Data that was missing was imputed using fully conditional specification imputation method for categorical and discrete variables in Proc Mi (27). All two-way interactions were also explored and included in the model if p<0.20. We then used backward elimination and removed non-significant variables one at a time until each variable retained in the model had a p-value < 0.05. All analysis for this paper was conducted in SAS software (Version 9.3, 2012, SAS Institute, Cary, NC).

RESULTS

Characterization of school nutrition and physical activity environment

We created z-scores for each issue-specific score so that we could assess comparisons between scores. We found the highest mean value in the school meal quality and availability score and the lowest mean value in the sports offerings and participation score. The greatest variation was found in the food fundraising policies score and the least variation was in the school meal quality and availability score. **Table 5.3** shows the descriptive characteristics for all school N&PA issue-specific scores. Concerning skewness and kurtosis, the issue-specific scores have relatively small deviations from zero, indicating that the scores are relatively normally distributed. As expected, we found generally low Cronbach alphas and mean inter-item correlations.

Table 5.3. Characteristics of school issue-specific scores

Issue-specific scores	No. of items	Raw scores[a] Mean (SD)	Raw scores[a] Range	Raw scores[a] Total poss.	Standardized scores[b] Mean (SD)	Standardized scores[b] Range	Score diagnostitics Kurtosis[c]	Score diagnostitics Skewness[d]	Score diagnostitics Chronbach alpha[e]	Score diagnostitics mean r
School meal quality and availability	106	130 (12)	108, 154	208	6.3 (0.6)	5.2, 7.4	0.099	0.049	0.65	0.105
Food fundraising policies	15	14 (5)	2, 22	30	4.8 (1.7)	0.7, 7.3	0.633	-0.069	0.56	0.105
General healthy eating promotion	13	10 (2)	5, 12	18	5.5 (1.1)	2.8, 6.6	0.921	-0.871	0.39	0.104
Quality of physical education	21	21 (4)	15, 26	35	6.0 (1.1)	4.3, 7.4	-1.041	-0.523	0.54	0.103
Sport offerings and participation	6	7 (2)	5, 11	21	3.4 (0.9)	2.4, 5.2	-0.970	0.392	0.24	0.157
General physical activity promotion	39	40 (6)	33, 52	65	6.2 (0.9)	5.1, 8.0	-0.144	0.650	0.67	0.11

[a] Raw scores were calculated by summing all variables within each score. The mean, standard deviation, range and total possible points within a score are presented.
[b] Standardized scores were calculated by taken the difference between the raw score and the total possible points for that score and dividing it by the total possible points. 10 is the maximum standardized score.
[c] Kurtosis is a measure whether the data are peaked or flat relative to a normal distribution.
[d] Skewness is a measure of symmetry.
[e] Cronbach alpha is a measure of the degree to which the items in the score are intercorrelated.
[f] Mean r is the mean inter-item correlation

Table 5.4 presents the characteristics and issue-specific scores of the 17 schools. A majority of the schools were a single building that housed all grade levels and in rural, distant areas defined by being 5 to 25 miles from an urbanized area and being 2.5 to 10 miles from an urban cluster.

Table 5.4. Characteristics and school issue-specific environment scores of schools (n=17) participating in study

School characteristics				School scores, standardized					
School SES[a]	Type[b]	Enrollment[c]	Rural[d]	School meals	Food fundraising	General healthy eating	Physical education	Sports	General physical activity
High	6th to 12th	Large	Town	5.8	2.8	6.1	4.9	3.8	5.5
High	K to 8th	Large	Town	5.2	4.0	6.7	6.6	4.3	6.6
High	6th to 12th	Large	Rural, distant	6.7	7.3	4.4	7.4	5.2	6.0
High	K to 12th	Medium	Rural, distant	5.3	6.3	6.7	6.6	3.3	5.1
High	6th to 12th	Medium	Rural, distant	6.1	4.3	5.6	5.7	3.3	6.2
Medium	K to 12th	Medium	Rural, distant	6.6	4.0	5.5	4.3	2.4	6.3
Medium	K to 12th	Small	Rural, distant	6.5	5.7	6.1	7.1	2.9	6.0
Medium	K to 12th	Medium	Rural, distant	6.4	4.3	5.0	6.6	2.4	6.5
Medium	K to 12th	Small	Rural, distant	6.7	5.3	5.0	6.3	4.8	5.1
Medium	K to 12th	Small	Rural, remote	6.3	0.7	6.7	6.9	3.8	5.2
Medium	6th to 12th	Large	Town	6.1	7.0	6.1	4.9	2.9	8.0
Low	K to 12th	Medium	Town	5.8	3.7	4.4	6.3	2.4	6.9
Low	K to 8th	Large	Rural, distant	7.3	4.7	5.5	4.3	4.8	8.0
Low	K to 12th	Medium	Rural, distant	6.0	6.3	5.0	7.4	3.8	6.5
Low	K to 12th	Large	Rural, distant	6.0	3.3	6.7	6.3	2.4	5.4
Low	K to 12th	Small	Rural, distant	6.4	6.0	2.8	6.3	2.4	5.2
Low	K to 12th	Small	Rural, remote	7.4	6.0	4.4	4.3	3.8	6.9

[a] School SES was summarized into tertiles based the percentage of students at the school who receive free and reduced priced meals (<37, 37 to <48, and $\geq$ 48)
[b] Type of school captured by the number of grades in building (K through 12th, K through 8th, and 6th through 12th)
[c] Enrollment was summarized into tertiles (<435 students, 435 to <754 students, and > 754 students)
[d] Rurality was based on NCES codes (town, rural/distant, and rural/remote).

Figure 5.1 shows the non-significant trends between issue-specific scores, rurality, and school SES. Rural-remote areas tend to have higher school meal scores and sports scores but lower scores in all other areas.

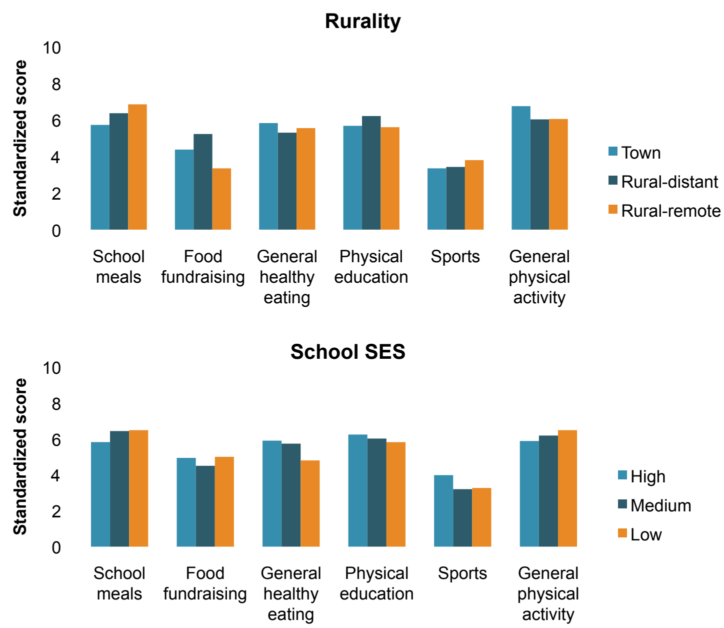


Figure 5.1. School issue-specific scores by rurality and by school SES

Low SES schools tended to have higher scores in school meals and general physical activity but lower scores in other areas. In general, we did not find that school scores clustered in any systematic fashion with regard to the school-level control variables. When we examined correlations between issue-specific scores we did not find any significant associations.

Associations between family income trajectory, issue-specific scores and BMI z-score

Table 5.5 presents the results of the multivariate analysis. In the first model, we examined the association between school issue-specific environment scores and BMI z-scores adjusted for important individual and school controls. The amount of variation explained by the model was calculated using the percent difference in covariance parameters between the model with time as the only covariate compared to the full multivariate model. The model explains 18% of the variation of the adolescents BMI z-score at the beginning of middle school (the intercept) and explains 3% of the variation of the change in BMI z-score during middle school (the slope). The data does not support a direct association between the school environment and change in BMI z-score during middle school.

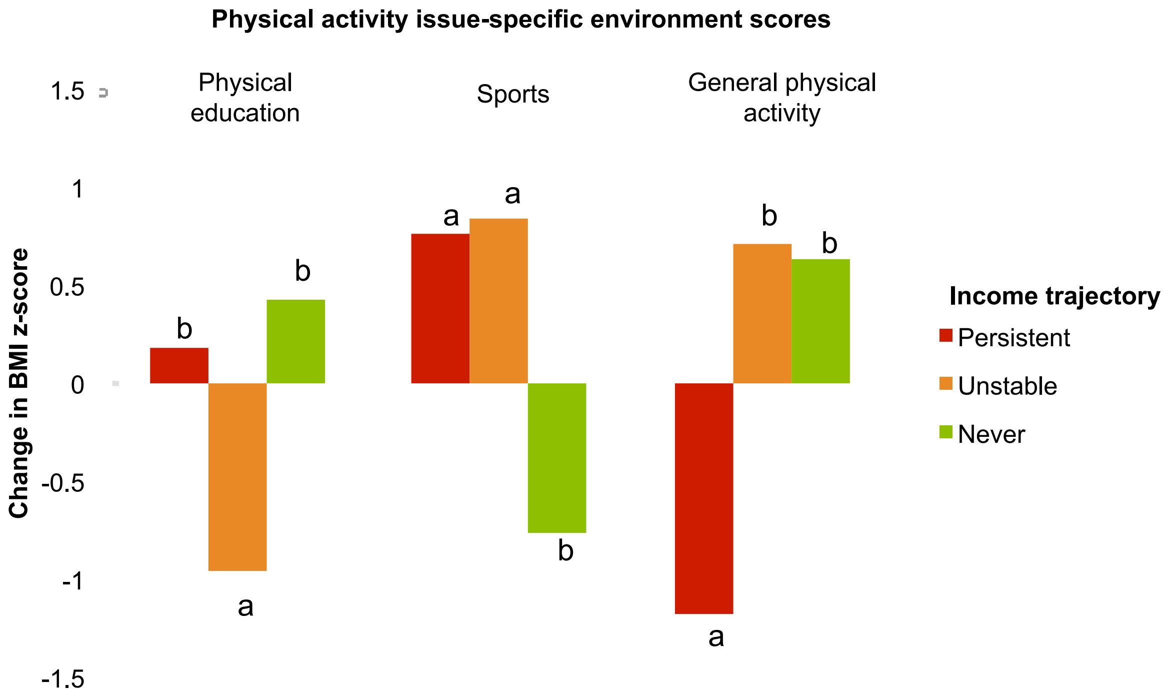
In the second model, we explored if the association between the school environment and BMI z-scores varies by family income trajectory. The addition of the interaction between income and school environment increased the amount of variation explained by the model to 24% of the adolescents BMI z-score at the beginning of middle school and 11% of the change in BMI z-score during middle school. After backward elimination, three physical activity issue-specific scores remain in the model. To illustrate the interaction between income trajectories and school environments, we calculated the estimated change in BMI z-score for adolescents with similar income trajectories between schools with the highest and lowest issue-specific score.

Table 5.5. Estimated linear mixed model coefficients for BMI z-score during middle school, 6th to 8th grade for school environment issue-specific scores by income trajectory

	Change in BMI z-score							
	Without interaction				With interaction[a]			
% of variation explained by model[b]:								
Starting BMI z-score		18%				24%		
Change in BMI z-score		3%				11%		
	Est.	SE	p-value		Est.	SE	p-value	
Intercept	0.399	1.648	0.809		2.239	1.945	0.251	
Time[c]	-0.038	0.021	0.071		-0.037	0.021	0.075	*
School meal quality and availability	0.013	0.008	0.138		-	-	NS	
Interaction income trajectory								
Persistent low-income	-	-	-		-	-	-	
Unstable low-income	-	-	-		-	-	-	
Never low-income	-	-	-		-	-	-	
Food fundraising policies	0.008	0.018	0.667		-	-	NS	
Interaction income trajectory								
Persistent low-income	-	-	-		-	-	-	
Unstable low-income	-	-	-		-	-	-	
Never low-income	-	-	-		-	-	-	
General healthy eating promotion	0.068	0.068	0.319		-	-	NS	
Interaction income trajectory								
Persistent low-income	-	-	-		-	-	-	
Unstable low-income	-	-	-		-	-	-	
Never low-income	-	-	-		-	-	-	
Quality of physical education	0.023	0.024	0.341		0.039	0.025	0.116	
Interaction income trajectory								
Persistent low-income	-	-	-		-0.023	0.048	0.634	
Unstable low-income	-	-	-		-0.126	0.057	0.027	*
Never low-income	-	-	-		-	-	-	
Sports offerings and participation	-0.068	0.041	0.098		-0.127	0.055	0.021	*
Interaction income trajectory								
Persistent low-income	-	-	-		0.254	0.099	0.011	*
Unstable low-income	-	-	-		0.266	0.104	0.011	*
Never low-income	-	-	-		-	-	-	
General physical activity promotion	0.001	0.016	0.580		0.034	0.021	0.115	*
Interaction income trajectory								
Persistent low-income	-	-	-		-0.095	0.034	0.006	**
Unstable low-income	-	-	-		0.004	0.038	0.924	
Never low-income	-	-	-		-	-	-	
Income trajectory								
Persistent low-income low-income	0.147	0.204	0.473		-6.669	3.041	0.029	*
Interaction with time	0.061	0.043	0.162		0.065	0.043	0.134	
Unstable low-income	-0.078	0.215	0.715		3.387	3.481	0.331	
Interaction with time	0.081	0.043	0.062		0.080	0.043	0.067	
Never low-income low-income	Ref	-	-		Ref	-	-	
Interaction with time	Ref	-	-		Ref	-	-	
Maternal overweight								
Obese/overweight	0.580	0.135	<0.0001	***	0.606	0.131	<0.0001	***
Normal/underweight	-	-			-	-		
Early-life growth trajectory								
High rising	0.426	0.186	0.0223	**	0.444	0.178	0.0133	*
Low rising	0.002	0.186	0.993		-0.288	0.181	0.113	
Stable	Ref	-	-		Ref	-	-	

[a] In the with interaction model backward elimination was used to achieve the most parsimonious m
[b] % variation explained by model was derived by taking the percent difference in covariance parameter estimates between the presented model and a basic model with time as the only predictor
[c]Time=0 at the start of middle school
Signicance level at *p <0.05; ** p <0.01; ***p <0.001
Models adjusted for sex, start of puberty, ADHD medication use and school SES

The interaction between the physical activity environment scores and family income trajectory is illustrated in **Figure 5.2**. The interaction between unstable low-income status and attendance at schools with better physical education scores was associated with an estimated reduction in BMI z-scores during middle school. The interaction between persistent low-income status and attendance at schools with better general physical activity environment scores was associated with a reduction in estimated BMI z-score during middle school.



Note: Different letters note significance differences at the level of <0.05
Adjusted for adjusting for sex, puberty status, ADHD medication use, maternal overweight/obese, early-life growth trajectory, school SES

Figure 5.2. Estimated change in BMI z-score during middle school, 6th to 8th grade, by issue-specific physical activity score and family income trajectory

Contrary to what we hypothesized, the interaction between persistent and unstable low-income status and attendance at schools with better sports environment scores was associated with an increase in BMI z-score. Interestingly, the interaction between never low-income status and attendance at schools with better sports environment scores was associated with a reduction in BMI z-score during middle school.

As for individual-level characteristics we found a non-significant trend between unstable low-income and change in BMI z-score during middle school (p=0.06). Adolescents with unstable low-income status tended to increase their BMI at a rate of 0.08 BMI z-score units per year. Maternal overweight/obesity and adolescent BMI z-score were strongly associated. Adolescents with an overweight/obese mother had an estimated BMI z-score that was 0.58 BMI z-score unit higher than adolescents with a normal/underweight mother. Adolescents with high-rising early-life growth trajectories, characterized by being larger at birth and then a rapid growth by the age 2, had an estimated BMI z-score that was 0.43 units higher than adolescents with stable early-life growth trajectories.

DISCUSSION

In this study we created a multidimensional assessment tool to characterize the school environment. This tool enabled us to examine whether the N&PA environments varied across different aspects of the environment within schools, as well as, between schools. We addressed three current gaps in the school environment assessment research. First, we examined both nutrition and physical activity environments, which allowed us to investigate environmental factors on both sides of the energy balance equation. Second, we used a multidimensional assessment of the nutrition and physical activity environment while most studies focused on one aspect of the environment. Finally, the assessment combined both researcher observation and questionnaires of key staff; this allowed for multiple perspectives and a more comprehensive characterization of the school environment.

The results we present offer new information on the middle school N&PA environments in rural schools. We found that when the school environment was divided into issue-specific scores, not only was there variation between schools, but within schools as well. Our findings suggest that in the sample the schools are not simply health-promoting or less health-promoting. Instead, each school had areas that needed improvement that were not systematic to their location, SES, type or enrollment. This work highlights the need for schools, researchers, and policy makers to make an initial assessment of the school environment so interventions can be tailored to those issue-specific aspects of the environment that need improving.

To our knowledge, previous studies that have examined the association between the school environment and BMI have not explored whether individual characteristics might modify these relationships. A strength of the study is that we address changes in

BMI z-score in the context of its biological, social and environmental determinants. In the sample, we found that family income trajectory moderated the association between aspects of the physical activity school environment and BMI z-score during middle school. We are encouraged by the finding that better physical activity promotion scores were associated with a reduction in BMI z-score for persistent low-income adolescents during middle school. The general physical activity promotion score was comprised of many of the attitudes and beliefs held by the principal and PE teacher. The finding suggests the potential importance of key figures in the school who value physical activity to find ways to promote physical activity outside of physical education and sports offerings.

We were surprised to find that sports participation/offerings environment score was associated with a lower BMI z-score in never low-income adolescents, while adolescents of persistent or unstable low-income trajectories actually had an associated increase in BMI z-score. We hypothesize that there might be barriers for adolescents of lower income to participate in sports activities. For example, only a quarter of the schools in the sample provide a late activity bus every day of the week, creating a potential barrier for rural low-income adolescents to participate in these activities.

Overall, we did not find strong evidence that the school environment explains much of the variation in BMI during middle school. There are three potential explanations for these results. First, in the models we see little change in BMI z-score during middle school (estimate=-0.04 BMI z-score units per year). This suggests that the most significant changes in BMI z-score in the sample may have already occurred, prior to middle school. However, we do find non-significant trends for rising BMI z-scores during middle school among persistent and unstable low-income adolescents. This highlights the potential importance of accounting for individual characteristics when exploring the role of the environment on BMI as these adolescents have the greatest potential for change. Second, the sample was comprised of schools from one region. One surprising observation from the school assessments was the overall quality of the food service at the schools in the sample. This was reflected in the school meals score having the highest overall mean compared to the other scores. The rural small school districts were remarkably similar in their infrastructure and food delivery systems and this is also reflected in the small variation between schools in school meals score. Finally, the school environment is only one of many environments that adolescents spend time in. Therefore, unless the school environments are particularly poor and the individual particularly susceptible detecting changes may be difficult.

The findings of the study should be considered in the context of its limitations. The examination of rural populations is often logistically challenging due to the greater distances between schools, hospital, and clinics. The medical records obtained from this multi-site healthcare system, however, mitigates against attrition by retaining individuals even if they move within the 8 county region. In addition, free school-based clinics through the Bassett Healthcare system see children regardless of insurance, which facilitates the retention of more low-income adolescents in this study. While the exclusion criteria for school assessment contributed to selection bias in this sample, the sample did include all the public central school districts for the 8-county region. Therefore, it is a reasonable sample to explore whether rural public schools can address the environmental influences on weight status.

Along with attrition there are four additional limitations to our work. First, we did not have measures of physical activity or food intake that would link the school environment to weight status. Second, the measure of the school environment was at one time period and assumes that the school environment is static. It is likely that changes occurred during this three-year time span that the assessment could not capture. Third, the observational nature of the study limited the interpretation and there may be residual confounding that biases the results. Fourth, the sample was predominantly white and rural and the ability to generalize the findings to other racial or geographic populations is limited.

In the context of these limitations, further research is needed to explore our hypotheses in other larger samples. Future work is also needed to examine the concurrent and predictive validity of the assessment of the school environment in other samples.

Conclusion

By the time adolescents reach middle school they have been set on a BMI trajectory based on their biological and socioeconomic risk, however, due to rapid growth, increased autonomy, and the potential influence of environmental factors, adolescence remains a critical leverage point to change BMI. Our multidimensional assessment of the school environment reveals heterogeneity within and between schools, suggesting that solutions to address childhood obesity through the school environment will not be one-size-fits-all. While the findings are not conclusive, they highlight the potential role of the school physical activity environment on reducing BMI during middle school especially for particular income groups. This is particularly salient as rural children are less active than their suburban and urban counterparts.

REFERENCES

1. Lutfiyya MN, Lipsky MS, Wisdom-Behounek J, Inpanbutr-Martinkus M. Is rural residency a risk factor for overweight and obesity for U.S. children? *Obesity (Silver Spring)*. 2007;15(9):2348–2356.

2. Gauthier BM, Hickner JM, Noel MM. High prevalence of overweight children in Michigan primary care practices. An UPRNet study. Upper Peninsula Research Network. *J Fam Pract*. 2000;49(1):73–76.

3. Davis CL, Flickinger B, Moore D, et al. Prevalence of cardiovascular risk factors in schoolchildren in a rural Georgia community. *Am. J. Med. Sci*. 2005;330(2):53–59.

4. Hill JO, Peters JC, Catenacci VA, Wyatt HR. International strategies to address obesity. *Obes Rev*. 2008;9 Suppl 1:41–47.

5. Bronfenbrenner U, Morris PA. The Bioecological Model of Human Development. In: Damon W, Lerner RM, eds. *Handbook of Child Psychology*. Hoboken, NJ, USA: John Wiley & Sons, Inc. 2007.

6. Nader PR, Bradley RH, Houts RM, McRitchie SL, O'Brien M. Moderate-to-Vigorous Physical Activity From Ages 9 to 15 Years. *JAMA: The Journal of the American Medical Association*. 2008;300(3):295–305.

7. Lee SM, Burgeson CR, Fulton JE, Spain CG. Physical education and physical activity: results from the School Health Policies and Programs Study 2006. *J Sch Health*. 2007;77(8):435–463.

8. Centers for Disease Control and Prevention. Guidelines for school health programs to promote lifelong healhty eating. *MMWR Morb Mortal Wkly Rep*. 1996;45(RR-9):1–33.

9. Kubik MY, Lytle LA, Hannan PJ, Perry CL, Story M. The association of the school food environment with dietary behaviors of young adolescents. *Am J Public Health*. 2003;93(7):1168–1173.

10. Terry-McElrath YM, O'Malley PM, Delva J, Johnston LD. The school food environment and student body mass index and food consumption: 2004 to 2007 national data. *J Adolesc Health*. 2009;45(3 Suppl):S45–56.

11. Lytle LA. Measuring the Food Environment State of the Science. *Am J Prev Med*. 2009;36(4 Suppl):S134–S144.

12. Ferreira I, van der Horst K, Wendel-Vos W, et al. Environmental correlates of physical activity in youth – a review and update. *Obesity Reviews*. 2007;8(2):129–154.

13. Razani N, Tester J. Childhood Obesity and the Built Environment. *Pediatric Annals*. 2010;39(3):133.

14. Galvez MP, Pearl M, Yen IH. Childhood obesity and the built environment. *Current Opinion in Pediatrics*. 2010;22(2):202–207.

15. Skelton JA, DeMattia L, Miller L, Olivier M. Obesity and Its Therapy: From Genes to Community Action. *Pediatric Clinics of North America*. 2006;53(4):777–794.

16. Olson C. Bassett Mothers Health Project: Descriptive Statistics. 1999.

17. Anon. NYSED :: IRS :: Data Reporting. Available at: http://www.p12.nysed.gov/irs/data_reporting.html. Accessed March 26, 2011.

18. Anon. SHPPS - School Health Policies and Programs Study - DASH/HealthyYouth. Available at: http://www.cdc.gov/HealthyYouth/shpps/. Accessed February 7, 2011.

19. Swinburn B, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev Med*. 1999;29(6 Pt 1):563–570.

20. Jones BL, Nagin DS, Roeder K. A SAS Procedure Based on Mixture Models for Estimating Developmental Trajectories. *Sociological Methods & Research*,. 2001:374 –393 vol. 29:

21. Nagin DS. *Group-Based Modeling of Development*. Harvard University Press; 2005.

22. Clark LA, Watson D. Constructing Validity: Basic Issues in Objective Scale Development. *Psychological Assessment*. 1995;7(3):309–19.

23. Peterson RA. A Meta-analysis of Cronbach's Coefficient Alpha. *Journal of Consumer Research*. 1994;21(2):381–91.

24. Raudenbush DSW, Bryk AS. *Hierarchical Linear Models: Applications and Data Analysis Methods*. 2nd ed. Sage Publications, Inc; 2001.

25. Anon. Common Core of Data (CCD). Available at: http://nces.ed.gov/ccd/rural_locales.asp. Accessed July 9, 2012.

CHAPTER 6

General discussion

This research was motivated by the desire to understand the underlying risk factors for overweight and obesity in children. Fifteen years of growth data, a rich dataset of early-life risk factors, and a multidimensional assessment of the school environment provided a unique opportunity to explore the development of overweight and obesity from multiple theoretical perspectives. This general discussion summarizes the main conclusions for each research aim. Then, it outlines how the aims together make four unique contributions to the understanding of the development of overweight and obesity in children. The chapter concludes with a presentation of research limitations, the questions that remain, and recommendations for how to move forward.

Contributions for each aim

Each aim of this study addressed current gaps in our knowledge regarding the development of overweight and obesity in children. In Aim 1, family income trajectories identified through latent-class modeling were found to be associated with body mass index (BMI) z-score trajectories, in the context of early-life risk factors. In this sample overweight and obesity developed early in life with distinguishable BMI trajectories occurring in early childhood and carrying on through adolescence. It was hypothesized that children with poorer income trajectories are more likely to become overweight or obese controlling for early-life risk factors. The findings support this hypothesis. Persistently low-income children were more likely to be in the overweight-stable trajectory and downwardly-mobile children were more likely to be in the obese trajectory compared to children whose families did not experience low-income. To our knowledge, this is the first study to document associations between income trajectories and developmental trajectories of overweight and obesity throughout childhood.

In Aim 2, food insecurity early in life was found to be associated with rates of growth in infancy and childhood. It was hypothesized that the timing of and changes in food insecurity status have different consequences for a child's growth. The findings support this hypothesis. Compared to food-secure children, food-insecure children were smaller in early childhood, but their increased rate of growth resulted in a higher BMI z-score by the time they reached age 15. These results provide new evidence to suggest that the overall relationship between BMI and food insecurity varies across childhood. These results provide new insight into why findings from longitudinal studies in early childhood were not conclusive.

Finally, in Aim 3, family income trajectory was found to modify the relationship between the school nutrition and physical activity (N&PA) environment and change in BMI z-score during middle school. This final aim applied the understanding of individual risk accumulated between birth and adolescence and then investigated if the middle school environment played a role in reversing or preventing overweight and obesity in adolescence. It was hypothesized that the school environment impacts adolescents with poorer income trajectories more than it does those of higher income adolescents. The association between the school environment and change in BMI z-score was found to vary across income trajectory. Specifically, reductions in BMI z-score were associated with unstable and persistent low-income adolescents in schools with higher physical education and general physical activity promotion scores. Whereas, reductions in BMI z-score were associated with not-low-income adolescents in schools with better sports offerings and participation. These findings highlight the potential role of the school physical activity environment in reducing BMI during middle school for certain income groups.

Contributions of research as a whole

The aims of this dissertation together make four unique contributions to the understanding of the development of overweight and obesity in children**.** First, two aspects of growth were examined—trajectories and rates. Depending on the measure and stage of growth, different associations with risk factors were found. These differences suggest that how and when risk for overweight and obesity was measured—whether through trajectories or changes in growth—has important implications for understanding how overweight and obesity develops. For example, maternal risk-factors like gestational weight gain and smoking during pregnancy were associated with elevated growth early in life but not later, especially when early-life growth was included in the models. This suggests that the impact of gestational weight gain and smoking during pregnancy on growth later in childhood were mediated by early-life growth. Interestingly, social risks such as income trajectory and food insecurity were significantly associated with growth later in life, but not in infancy. Whereas, maternal overweight was consistently associated with elevated growth regardless of how or when it was measured. These findings have important implications for intervention, suggesting that early-life interventions should focus on maternal risk factors, while interventions later in life should focus on mitigating the effects of social disadvantage.

Second, income trajectory was found to capture more variation in BMI z-score trajectory membership than other measures of socioeconomic status (SES) in this sample. This finding supports an emerging body of research suggesting that it is the persistence and trajectory of the family's SES, rather than the overall level of deprivation, that impacts health and development (1–3). In this sample, children who were downwardly mobile were more likely become obese. While persistent low-income children were more likely to be in the overweight-stable trajectory, staying persistently overweight. The findings support the life course perspective concept that trajectories develop in concert and reinforce each other over time.

Third, lower SES children were more likely to have other early-life risk factors for the development of overweight and obesity. In Aim 1, children with poorer income trajectories were more likely to have mothers who were overweight, had excessive gestational weight gain, smoked during pregnancy, and were breastfed for less than 4 months. In Aim 2, children who became food insecure were more likely to have mothers who were overweight and had excessive gestational weight gain. Meanwhile, children who "stayed" or "moved out of" food insecurity were more likely to have unstable income trajectories and mothers who smoked during pregnancy, both risk factors for the development of overweight and obesity in children. This provides suggests that disadvantaged children have a disproportionate risk for the development of overweight and obesity compared to their higher SES counterparts. Income alone, as a variable, does not likely capture the full extent of their risk.

Finally, our findings support growing evidence that rural children are at high risk for overweight and obesity (4). Overweight and obesity in children cannot be measured with simple BMI cutoffs as in adults. Instead, overweight and obesity in children is based on a comparison to standard growth that is gender and age specific. In a healthy population, we expect approximately 15% of children to be classified as overweight and 5% as obese. In this sample, 35% of children are grouped in an overweight trajectory and 12% are grouped in the obese trajectory. The average rates of overweight and obesity in New York State are around 40% (5). The higher-than-expected proportion of overweight and obesity in the sample suggests that this population has unhealthy rates of growth. The sample also has high rates of food insecurity in early-life and dynamic changes in income throughout childhood making the findings of the studies particularly pertinent for this at-risk population.

These conclusions should be considered in the context of the limitations of this research. First, while the use of a rural, predominantly white population provides important insight into one at-risk population, the ability to generalize certain findings to other more racially and geographically diverse populations is limited. The findings related to biological risk factors, such as maternal overweight, gestational weight gain, and smoking during pregnancy, are likely applicable to other populations. Social and environmental risk factors are likely different in rural populations compared to urban populations making the generalizability of these findings limited. Second, the measure of income was only a dichotomous measure, below 185% of the poverty line or not. In the future, it would also be useful to have repeated measures of income as a continuous variable to investigate trajectories in overall income.

Moving forward from the contributions and limitations of this study there are three important areas to highlight for future work. First, some risk factors, like food insecurity, take time to development into elevated weight status in children. Fifteen years is a long time to wait for future work. In addition, once a child has reached overweight and obesity status it is difficult to reverse (6). Instead of using overweight and obesity as the barometer for child health, researchers should focus on finding ways to identify rapid growth and intervene in children to prevent unhealthy weight gain. To do this, parents, doctors and even schools need to monitor weight status and address rapid changes immediately. Discussions of a child's weight are often associated with blame and feelings of guilt and defensiveness, while doctors may feel there is little they can do. Future work to provide sensitive solutions to parents and doctor's reluctance to discuss and confront rapid weight gain in young children is needed.

Second, as the life course perspective, bio-ecological system theory, and our findings suggest, risk factors are tightly clustered and reinforce each other over time. This can present a pessimistic picture of how to prevent or reverse childhood obesity. However, this complex, repeated intersection of risk factors can also be an advantage. At the right turning point, changes in one risk factor may causes changes in others. Pregnancy has the potential to be a turning point in a woman's life. Pregnancy may make women more receptive to changes in behaviors that could influence their health trajectory and subsequently the health trajectory of their child. Finding which changes cause cascading effects in other aspects of a woman's life would provide concrete and positive ways to break the cycle of disadvantage from mother to child.

Finally, the school environment may be a critical avenue to reach the most at-risk children. In this sample, schools were concerned with both food insecurity and obesity in its students, which highlights the complex decisions that schools face in regards to child health. Providing salad bars or high-level interscholastic sports that low-income children cannot access will fail to improve health in the most-at-risk children. Therefore, research and interventions to identify and address barriers for low-income children are essential.

Conclusion

Our use of income trajectories provides new evidence that trajectories in overweight and obesity develop together with changes in SES. The use of different measures of growth brings new insight into how early-life risk factors impact growth in early life and later childhood. Finally, the impact of the middle school environment depends on an adolescent's SES. Taken together, the aims of this research tell a story about how the growth of children differs across SES. What we are confronted with is the all-too-familiar reality that low SES is clustered with a host of other biological and environmental risk factors. Teasing apart these risk factors has important implications for how we frame the discussion. Yet ultimately, it is the underlying social inequalities that produce these risk factors. This reality must be confronted. Childhood obesity is too prevalent and the consequences are too severe to not address both the immediate and underlying causes.

REFERENCES

1. Wethington E. An Overview of the Life Course Perspective: Implications for Health and Nutrition. Journal of Nutrition Education and Behavior. 2005 May;37(3):115–20.

2. Scharoun-Lee M, Kaufman JS, Popkin BM, Gordon-Larsen P. Obesity, race/ethnicity and life course socioeconomic status across the transition from adolescence to adulthood. Journal of Epidemiology and Community Health. 2009 Feb 1;63(2):133 – 139.

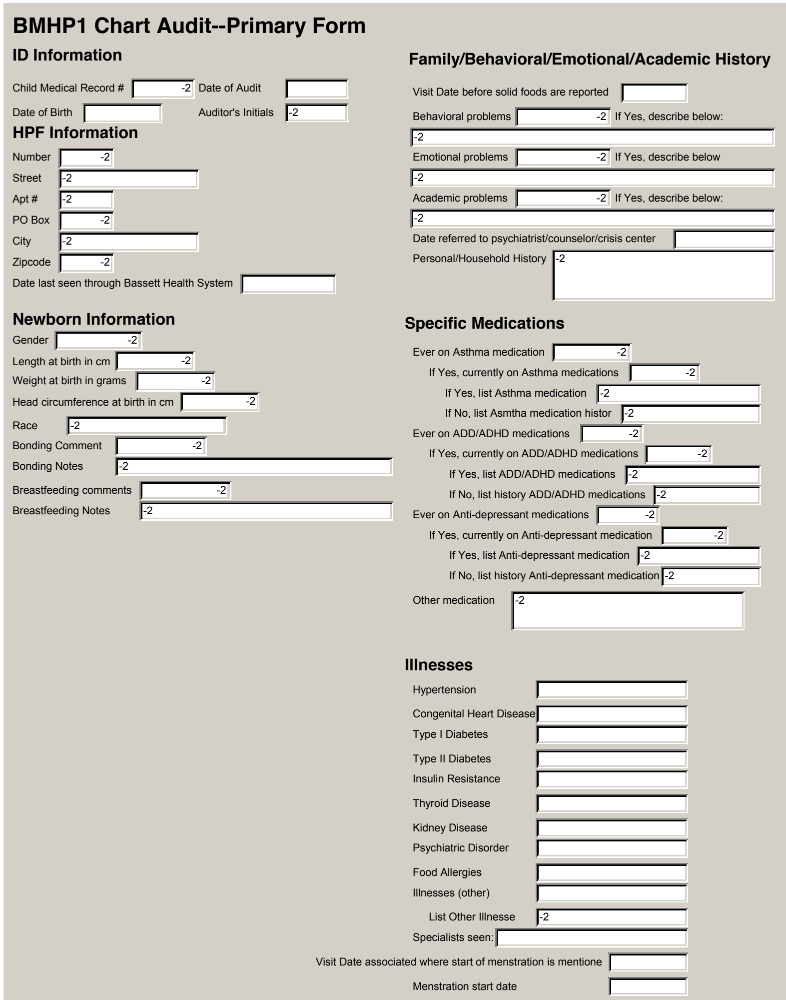
3. Damon W, Lerner RM. Handbook of Child Psychology: Theoretical models of human development. John Wiley and Sons; 2006.

4. Lutfiyya MN, Lipsky MS, Wisdom-Behounek J, Inpanbutr-Martinkus M. Is rural residency a risk factor for overweight and obesity for U.S. children? Obesity (Silver Spring). 2007 Sep;15(9):2348–56.

5. Obesity and Overweight for Professionals: Childhood: Data | DNPAO | CDC [Internet]. [cited 2012 Aug 7]. Available from: http://www.cdc.gov/obesity/data/childhood.html

6. Guo SS, Wu W, Chumlea WC, Roche AF. Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. Am J Clin Nutr. 2002 Sep 1;76(3):653–8.

APPENDIX A: Forms used for medical chart audits



BMHP1 Chart Audit--Primary Form

ID Information

Child Medical Record # -2
Date of Audit
Date of Birth
Auditor's Initials -2

HPF Information

Number -2
Street -2
Apt # -2
PO Box -2
City -2
Zipcode -2
Date last seen through Bassett Health System

Newborn Information

Gender -2
Length at birth in cm -2
Weight at birth in grams -2
Head circumference at birth in cm -2
Race -2
Bonding Comment -2
Bonding Notes -2
Breastfeeding comments -2
Breastfeeding Notes -2

Family/Behavioral/Emotional/Academic History

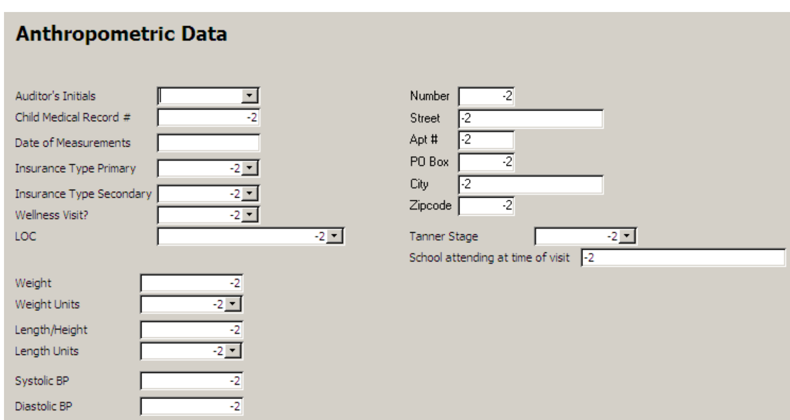
Visit Date before solid foods are reported
Behavioral problems -2 If Yes, describe below:
-2
Emotional problems -2 If Yes, describe below
-2
Academic problems -2 If Yes, describe below:
-2
Date referred to psychiatrist/counselor/crisis center
Personal/Household History -2

Specific Medications

Ever on Asthma medication -2
If Yes, currently on Asthma medications -2
If Yes, list Asthma medication -2
If No, list Asmtha medication histor -2
Ever on ADD/ADHD medications -2
If Yes, currently on ADD/ADHD medications -2
If Yes, list ADD/ADHD medications -2
If No, list history ADD/ADHD medications -2
Ever on Anti-depressant medications -2
If Yes, currently on Anti-depressant medication -2
If Yes, list Anti-depressant medication -2
If No, list history Anti-depressant medication -2
Other medication -2

Illnesses

Hypertension
Congenital Heart Disease
Type I Diabetes
Type II Diabetes
Insulin Resistance
Thyroid Disease
Kidney Disease
Psychiatric Disorder
Food Allergies
Illnesses (other)
List Other Illnesse -2
Specialists seen:
Visit Date associated where start of menstration is mentione
Menstration start date



Anthropometric Data

Auditor's Initials
Child Medical Record # -2
Date of Measurements
Insurance Type Primary -2
Insurance Type Secondary -2
Wellness Visit? -2
LOC -2

Weight -2
Weight Units -2
Length/Height -2
Length Units -2
Systolic BP -2
Diastolic BP -2

Number -2
Street -2
Apt # -2
PO Box -2
City -2
Zipcode -2
Tanner Stage -2
School attending at time of visit -2

APPENDIX B: Variables and sources from medical charts

Primary Form			
List of Variables	**Coding**	**Source in Medical Record**	**Notes**
MNR	6 or 7 digit number	Number assigned by Bassett Healthcare specifically for that Child	
Date of Audit	8 digit date	Date Audit of Chart began	Some charts may be in different physical locations so the date refers to the start date of the audit
Auditors Initials	MD=Margaret Demment, SC=Stacy Carling		
Number	Number	House number corresponding to Current Address in HPF (Bassett's Online Medical Records Database)	
Street	Text	Street corresponding to Current Address in HPF (Bassett's Online Medical Records Database)	
Apt #	Text	Apartment number or unit corresponding to Current Address in HPF (Bassett's Online Medical Records Database)	
PO Box	Number	Post Office Box corresponding to Current Address in HPF (Bassett's Online Medical Records Database	
City	Text	City corresponding to Current Address in HPF (Bassett's Online Medical Records Database)	
Zipcode	Number	Zipcode corresponding to Current Address in HPF (Bassett's Online Medical Records Database)	
Date Last seen	8 digit date	Last date in HPF/Paper records/Microfilm with actual documentation	
Gender	1=female, 2=male	SX on Medical Record Label	
Length at birth in cm	Number	Newborn Assessment Sheet	
Weight at birth in g	Number	1) Newborn Assessment Sheet or 2)Delivery Information or 3)Physician Attestation Sheet	
Head circumference in cm	Number	Newborn Assessment Sheet	
Race	1=white, 2=black, 3=Amerindian, 4=Chinese, 5=Japanese, 6=Hawaiian, 7=Filipino, 8=Other Asian, 9=Asian Indian, 10=Korean, 11=Samoan, 12=Vietnamese, 13=Guamanian	Newborn Admission Form	
Bonding Comments	1=well, 2=poor, 3=no mention	1)Newborn Discharge Summary or 2) Closest Nurse/Doctor's comment to discharge mentioning mother/father bonding with child	
Bonding Notes	text	Any specific notes pertaining to bonding comments	
Breastfeeding Comments	1=well, 2=poor, 3=no mention	Nursery Record Form, under Feeding:Breast, using most recent before discharge	
Breastfeeding Notes	text	Any specific notes pertaining to breastfeeding comments	

Visit Date before solid foods are reported	Date	Pediatric Health Maintenance Record under Feeding, Question 2	Using visit date before reported, as Dr. Kjolhede suggested this would likely be when the Doctor reccomended solid foods
Behavioral Problems	1=yes, 2=no	Progress Notes, Early Adolescent (11 to 15 years) Questionaire	Focus on events that suggested child was acting out (e.g. fights in school).
If yes, describe behavioral problems	text	Details about behavioral problems	
Emotional Problems	1=yes, 2=no	Progress Notes, Early Adolescent (11 to 15 years) Questionaire	Focus on concerns regarding specific feelings such as anger, sadness, anxiety, etc. Child not necessarily acting on these feelings.
Academic Problems	1=female, 2=male	Progress Notes, Early Adolescent (11 to 15 years) Questionaire	Focus on concerns with academic performance.
Date referred to physchiatrist/counselor/crisis center	Date	Progress Notes, Rererrals	Date associated with referral by doctor.
Personal/Household History	Text	Progress Notes, Pediatric Health Maintence Records, Early Adolescent (11 to 15 years) Questionaire	Anything pertaining to: family structure, living arrangements, major family events, ongoing diet concerns, and menstration with associated date in ().
Ever on Asthma medication	1=yes, 2=no	Progress Notes, Medication Lists	
If yes, currently on Asthma medications	1=yes, 2=no	Most recent visit documentation	
If Yes, list Asthma medications	text	Most recent visit documentation	List medication with earliest date prescribed/mentioned in () and notes on severity of asthma
If No, list Asthma medications	text	Any documentation on medications	List any previous medications with earliest date prescribed/mentioned
Ever on ADD/ADHD Medications	1=yes, 2=no	Progress Notes, Medication Lists	
If yes, currently on ADD/ADHD medications	text	Most recent visit documentation	List medication with earliest date prescribed/mentioned in ()
If No, list ADD/ADHD medications	text	Any documentation on medications	List any previous medications with earliest date prescribed/mentioned
Ever on Anti-depressant Medications	1=yes, 2=no	Progress Notes, Medication Lists	
If yes, currently on Anti-depressant Medications	text	Most recent visit documentation	List medication with earliest date prescribed/mentioned in ()
If No, listAnti-depressant Medications	text	Any documentation on medications	List any previous medications with earliest date prescribed/mentioned
Other medications	text	Any documentation on medications	List any medications that may have an effect on weight

Hypertension	Date	Progress Notes, Problem List	Date associated with diagnosis
Congenital Heart Disease	Date	Progress Notes, Problem List	Date associated with diagnosis
Type I Diabetes	Date	Progress Notes, Problem List	Date associated with diagnosis
Type II Diabetes	Date	Progress Notes, Problem List	Date associated with diagnosis
Insulin Resistance	Date	Progress Notes, Lab workups	Date associated with diagnosis
Thyroid Disease	Date	Progress Notes, Problem List	Date associated with diagnosis
Kidney Disease	Date	Progress Notes, Problem List	Date associated with diagnosis
Psychiatric	Date	Progress Notes, Problem List	Date associated with diagnosis
Food Allergies	Date	Progress Notes, Problem List	Date associated with diagnosis
Illnesses (other)	Date	Progress Notes, Problem List	Date associated with diagnosis
List Other Illnesses	Text	Progress Notes, Problem List	
Specialists seen	Text	Progress Notes, Problem List	Any specialists seen for issues internal pathology
Visit Date associated where start of menstration is mentioned	Date	Adolescent Questionaire, Progress Notes	
Menstration start date	Date	Adolescent Questionaire, Progress Notes	
Visit Form			
List of Variables	Coding	Source in Medical Record	Notes
Auditors Initials	MD=Margaret Demment, SC=Stacy Carling		
Child Medical Chart ID	6 or 7 digit number	Number assigned by Bassett Healthcare specifically for that Child	
Date of Measurements	Date	Date associated with visit	
Insurance Type Primary	1=Medicaid, 2=CHP, 3=HMO, Private, PPPO, 4=Self-pay	FSC or PL on Medical Chart Label or on 1st insurance listed on Admission Sheet or 1st insurance listed on chart front label	1st billed insurance associated with visit
Insurance Type Secondary	1=Medicaid, 2=CHP, 3=HMO, Private, PPPO, 4=Self-pay	2nd insurance listed on Admission Sheet or 2nd insurance listed on chart front label	2nd billed insurance associated with visit
Wellness Visit?	1=yes, 2=no	Forms used for visit	If used Pediatric Health Maintenance Record or specific mention of visit being a wellness visit coded as yes all others coded as no.
LOC	text	1) LOC on Medical Chart Label or 2)Other mention on forms	
Weight	number	Anywhere we see weight and height/Tanner Stage/Address/Insurance Change on same visit date	Only include measured weights medical professionals, exclude self report, weights for ER visits are excluded because they have no height associated with them.
Weight units	1=oz, 2=lbs, 3=g, 4=kg	Units associated with weight	
Length/Height	number	Anywhere we see a height and weight	
Length units	1=inches, 2=feet, 3=cm, 4=m	Units associated with height	

Systolic BP	number	Anywhere BP is taken with height and weight	
Diastolic BP	number	Anywhere BP is taken with height and weight	
Number	number	House number corresponding to address at time of visit	
Street	text	Street corresponding to address at time of visit	
Apt #	text	Apartment number or unit corresponding to address at time of visit	
PO Box	number	Post Office Box corresponding to address at time of visit	
City	text	City corresponding to address at time of visit	
Zipcode	number	Zipcode corresponding to address at time of visit	
Tanner Stage	1,2,3,4,5,6	Progress Notes, Pediatric Health Maintence Records, Early Adolescent (11 to 15 years) Questionaire	
School attending at time of visit	text	Progress Notes, Pediatric Health Maintence Records, Early Adolescent (11 to 15 years) Questionaire	

APPENDIX C: Existing Instruments for Evaluating School Environment

INSTRUMENT/STUDY	N OR PA	ENVIRONMENT	UNIT OF ANALYSIS	INSTRUMENT TYPE	RELIABILITY	VALIDITY
Kubik (2002)[19]	N	Socio-cultural, Political	Teacher	Self Administered Questionnaire	Cronbach's alpha	Face
Kubik (2005)[20]	N	Political	School Administrator	Self Administered Questionnaire	Cronbach's alpha	
Murnan (2006)[21]	N	Socio-cultural, Political	Parents	Self Administered Questionnaire	Test-retest	Face, Content, Construct
Thompson (2007)[22]	N	Physical, socio-cultural	Students	Self Administered Questionnaire	Cronbach's alpha, test-retest	Face
Evans (2009)[23]	N	Physical, political, socio-cultural	Administrators	Self Administered Questionnaire		
Ward (2009)[24]	N/PA	Physical, political, socio-cultural	Administrator	Self Administered Questionnaire	Intraobserver reliability	
Benjamin (2007)[25] NAP SACC	N/PA	Physical, political, socio-cultural	Administrators	Self Administered Questionnaire	Inter-rater reliability, test-retest, criterion validity	
Scrabis-Fletcher (2010)[26]	PA	Socio-cultural	Students	Self Administered Questionnaire		Construct
HSAT[27]	N/PA	Physical, political, socio-cultural	Administrators	Self Administered Questionnaire	?	?
SHI (2005)[28]	N/PA	Physical, political, socio-cultural	Administers	Self Administered Assessment	*Not meant to be used as a research tool*	
Healthy Vending Machine Environment Assessment	N	Physical	Researcher	Assessment		
SHPPS (1999)[5]	N/PA	Physical, political, socio-cultural	Administrators	Self Administered Questionnaire		Face
Eat well be active (2009)	N/PA	Physical, economic, political, socio-cultural	Administrators	Self Administered Questionnaire		

APPENDIX D: Environmental Grid Breakdown for Nutrition

NUTRITIONAL ISSUE SPECIFIC CATEGORY	PHYSICAL **What is available . . .**	ECONOMIC **What are the costs/revenue . . .**	POLITICAL: **What are the rules . . .**	SOCIO-CULTURAL **What are the attitudes and beliefs . . .**
School meals	• Types? (breakfast, lunch, afterschool) • Offerings? (whole grains, salad bar, drink selection etc.) • Facilities? (kitchen and cafeteria) • Numbers? (how many students participate?)	• Of school meals and who subsidizes them? (self-sustaining or funding from district?) • For students and how do they pay for meals? • Of food items (healthy vs. less healthy)?	• For who makes decisions about food service? Who else has input? • About students leaving campus during lunch periods?	• About the role of school food service? • About facilitators/barriers to providing healthier options?
Fundraisers (for sports teams and school clubs)	• Frequency? • Placement? (in cafeteria) • Offerings? (nutritional quality of food sales)	• For school teams/clubs, are they required to fundraise?	• About limitations/restrictions about what can be sold?	• Fundraisers in school?
General healthy eating promotion	• Advertisements on school grounds? (placement, content) • Vending machines? (placement, offerings) • Snack bar? (offerings)	• For advertisement on school grounds? • For where funds from vending machines go? • For where funds from school snack bar go?	• About access to and offerings of vending machines and snack bar? • About when and where students can eat or drink? • About teachers/staff using food as an incentive/reward?	• About practices that may improve healthy eating? • How often do teachers/staff use food as an incentive/reward? • Teachers/staff as role models?

APPENDIX D: Environmental Grid Breakdown for Physical Activity

PHYSICAL ACTIVITY ISSUE SPECIFIC CATEGORGY	PHYSICAL **What is available . . .**	ECONOMIC **What are the costs/revenue . . .**	POLITICAL: **What are the rules . . .**	SOCIO-CULTURAL **What are the attitudes and beliefs . . .**
Physical Education	• Facilities (quantity and quality)? • Teachers? (number, ratio to students, training) • Activities?	• Is PE limited by financial resources?	• PE graded? • Amount of time?	• Role of PE for students? • About facilitators and barriers to increasing PE time/quality?
Interscholastic and Intramural Activities	• Facilities (quantity and quality)? • Coaches? (number and training) • Late bus? • Activities? (ratio to students)	• Clubs/teams required to be self-sustaining? • Teachers paid for supervising intramurals/clubs? • Coaches paid for supervising team activities?	• Participation?	• Ratio of participation of girls and boys? • Priority?
General physical activity promotion (Active transport)	• Structures for active transport? (sidewalks, bike racks) • Proportion of students who actively transport to school?	• Financial barriers to active transport? (sidewalks, cross guards, etc)	• About using physical activity as a punishment? • Permitting students to use facilities during non-PE hours or after school hours?	• Use of facilities for community organizations or citizens? • Practices around physical activity (how often do teachers us PA as a punishment?) • About active transport (walking or biking) to school? • Are facilities used often?

APPENDIX E: School assessment tool

Information about you . . .

1. What is your gender? ☐ Male ☐ Female

2. How many years have you served in this position? ____ years

3. What level of education have you completed? *(Check all that apply)*
☐ High school or GED
☐ Associates Degree
☐ Undergraduate Degree, if yes, please specify major:______________________________________
☐ Masters Degree, if yes, please specify area(s):____
☐ Doctoral Degree, if yes, please specify area(s):____

General questions about school

4. When do classes begin each day? ___ : ___

	Yes	No
5. Is the start time the same for all grades?	☐	☐ --> If no, please specify other start time: ___ :___

6. Does your school offer Channel One in classrooms? ☐ Yes ☐ No

7. Does your school participate in the BackPack Program (food assistance backpacks for kids)? ☐ Yes ☐ No

Questions about School Meals . . .

8. Are students allowed to leave campus for the lunch period? ☐ Yes ☐ No
   If yes, under what circumstances: ____

9. How influential are the following people in making decisions about what food is offered?

		None	A little	Somewhat	A lot	Completely
a	School Food Service Manager	☐	☐	☐	☐	☐
b	District Food Service Manager	☐	☐	☐	☐	☐
c	Food systems company	☐	☐	☐	☐	☐
d	School nutrition/health committee	☐	☐	☐	☐	☐
e	Principal	☐	☐	☐	☐	☐
f	Parents	☐	☐	☐	☐	☐
g	Students	☐	☐	☐	☐	☐
h	Other, please specify:_______________					

10. Do all students eat lunch at the same time? ☐ Yes ☐ No

If YES, What time do you usually start serving lunch to students? ___ : ___
What time do you usually stop serving lunch to students? ___ : ___

If NO, please specify other lunch periods:

1. Start serving lunch to students? ___ : ___
   Stop serving lunch to students? ___: ___

2. Start serving lunch to students? ___ : ___
   Stop serving lunch to students? ___: ___

11. Do you agree or disagree with the following statements about the role of your school's cafeteria?

	Strongl y agree	Agre e	Neutral	Disagre e	Strongly disagree
Provide a food service	☐	☐	☐	☐	☐
Insure students get enough calories	☐	☐	☐	☐	☐
Insure students don't get too many calories	☐	☐	☐	☐	☐
Make a profit for the food service company	☐	☐	☐	☐	☐
Make a profit for the school needs	☐	☐	☐	☐	☐
Support classroom nutrition education	☐	☐	☐	☐	☐
Provide and promoting healthy food	☐	☐	☐	☐	☐
Other, please specify:_____________________					

12. In the last year, did any of the following factors help your school's cafeteria to provide healthier food

choices? (C*heck* *all* *that apply)*

- ☐ Networking with other schools in the area
- ☐ Assistance from health professionals
- ☐ Support from teaching staff
- ☐ Requests from parents
- ☐ Training for food service staff
- ☐ Easy access to healthier food choices
- ☐ Knowledge of the childhood obesity problem
- ☐ Special deals on healthier food products
- ☐ More storage space available
- ☐ Promotions of healthier food products
- ☐ Suitable equipment now available
- ☐ Information from media
- ☐ Other, please specify:___________________________________

13. In the last year, which of the following limited your school's cafeteria from providing more healthy food choices? (Check all that apply)

- ☐ None, already sell plenty of healthy choices
- ☐ Need to make a profit, selling healthier food is less profitable
- ☐ Special deals from distributers for less healthy food
- ☐ Can't get easy access to healthy food products
- ☐ Lack of demand from students
- ☐ Lack of support from parents
- ☐ Lack of support from food service staff
- ☐ Lack of support from school administration
- ☐ Competition with a la carte options
- ☐ Have tried, too much waste
- ☐ Lack of time to prepare, more labor intensive
- ☐ Lack of volunteers (school staff or parents)
- ☐ Healthy food is too expensive to buy for school meals
- ☐ Poor shelf life of fresh food
- ☐ Lack of storage space
- ☐ Lack of suitable equipment, please specify:.______________________________
- ☐ Lack of preparation area
- ☐ Lack of display space
- ☐ Other, please specify:.______________________________________

Questions about Fundraisers

14. On average how often do school fundraisers (for clubs or sports teams) offer food items for sale to students at the school during the school day?

- ☐ Daily
- ☐ More than once a week
- ☐ Once a week
- ☐ Once every two weeks
- ☐ Once a month
- ☐ Less than once a month
- ☐ Never (If never, please skip to next section)

15. Does your school have any written procedures or guidelines shared with students and staff that address the nutrient quality (fat content, calories, etc) of food and drink items in:

	Yes	No
Classroom fundraisers	☐	☐
School-wide fundraisers	☐	☐
Other fundraisers (Girl Scouts, sports teams, clubs)?	☐	☐
During sporting events	☐	☐

16. How often are chocolate, candy and/or baked goods are used in . . .

		Never	Rarely	Sometimes	Often	Always
a	Classroom fundraising	☐	☐	☐	☐	☐
b	School-wide fundraising	☐	☐	☐	☐	☐
c	Fundraising by school sports teams and/or clubs	☐	☐	☐	☐	☐

17. Do club food sales ever occur in the cafeteria during lunchtime? ☐ Yes ☐ No

18. Are school teams/clubs required to fundraise to sustain their programs? ☐ Yes ☐ No

19. In the last year, have there been any discussions about restrictions for fundraising foods in the following groups? *(check all that apply)*

- ☐ School district
- ☐ School administration
- ☐ School staff
- ☐ Parents or PTA
- ☐ Students
- ☐ Our school does not think that restrictions are necessary for fundraising foods
- ☐ Our school already has restrictions on fundraising foods

Questions about General Healthy Eating Promotion . . .

	Yes	No
20. Does your district have a contract with a soft drink bottler, such as Coca-Cola, Pepsi-Cola, or Dr. Pepper, to sell soft drinks at schools in your school?	☐	☐
21. Are there soft drink machines at the school owned by soft drink companies, for which your district/school receives a percentage of the sales? If yes, what do those sales go to: ______________________________	☐	☐
22. Does your district/school receive incentives (e.g. cash rewards, donations of equipment, supplies, or other donations) from a soft drink bottler based on sales? If yes, what do those incentives go to: ____________________________	☐	☐

23. How many food vending machines are accessible to students on the school premises?
___ number inside
___ number outside

24. How many drink vending machines are accessible to students on the school premises?
___ number inside
___ number outside

25. Does the school make a profit from vending machines?
☐ Yes ————————————————> If yes, what do those funds get used for?
Please specify: ______________________________
☐ No

26. Are there any restrictions/guidelines/policies about when students can buy from vending machines?
☐ Yes ————————————————> If yes, please specify: ________________________
☐ No

27. Is there a school snack bar with food and/or drink available to students?
☐ Yes
☐ No

28. What do funds from the school snack bar get used for? ________________________

29. Are there any restrictions/guidelines/policies about what times can students buy from snack bar?

☐ Yes ————————————————> If yes, please specify: ________________________
☐ No

30. Which of the following practices (what your students are allowed to do on a regular basis) does your school allow?

Students are allowed to . . .	Yes	No	Sometimes

a	Have food in the classroom	☐	☐	☐ Please specify:
b	Have beverages in the classroom	☐	☐	☐ Please specify:
c	Have food in school hallways	☐	☐	☐ Please specify:
d	Have beverages in school hallways	☐	☐	☐ Please specify:

31. Do you agree or disagree with the following statements?

	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
a. It is important for school staff to role model healthy eating behaviors for students	☐	☐	☐	☐	☐
b. Healthy eating for students is a priority in this school	☐	☐	☐	☐	☐

Questions about Physical Education

32. Do you agree or disagree with the following statements about what limits the amount of physical education can offer?

	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Not enough time in the school day	☐	☐	☐	☐	☐
Not enough money to support more PE teacher hours	☐	☐	☐	☐	☐
Not enough equipment for students during PE period	☐	☐	☐	☐	☐

Other, please specify: ____

33. Does your school have any policies (written procedures or guidelines share with students and staff) regarding whether . . .

		Yes	No
a	Students earn grades for required PE classes?	☐	☐
b	PE grades count the same as other classes?	☐	☐
c	All PE teachers are certified PE specialists?	☐	☐
d	Students can substitute PE classes with other classes (ROTC, band)?	☐	☐

34. Does your school have any practices regarding . . .

		Yes	No
a	The use of physical activity as a punishment strategy for inappropriate behavior (making students run laps or do push-ups as a consequence of inappropriate behavior)?	☐	☐
b	Withholding PE class as a punishment strategy?	☐	☐
c	The maximum student-to-teacher ratio for PE classes?	☐	☐
d	The provision of individualized physical activity/fitness plans?	☐	☐

35. How many quarters, trimesters, or semesters per year are students in your middle or junior high school required to take PE?

___ Quarter(s)
___ Trimester(s)
___ Semesters(s)

Interscholastic Sports/Activities

36. Are there sports/activities that the school would like to offer but cannot because there are not facilities for it?

☐ Yes ————————> If yes, please specify: ______________________
☐ No

37. Approximately what percent of your coaches are . . .

_____ % Non- PE teachers at this school
_____ % PE teachers
_____ % Parents
_____ % Other, please specify: ___________________________________

38. How many days a week (on average) is an activity bus (late bus) available to students?

☐ Never
☐ <1 day/week
☐ 1-2 days/week
☐ 3-4 days/week
☐ 5 days/week

39. Must students pay an activity fee to participate in interscholastic activities?

☐ Yes → If YES, is the fee waived if a student cannot afford to pay? ☐ Yes ☐ No
☐ No

Intramural Sports/Activities

40. In the last year, did the school offer organized physical activities (excluding formal PE) to students during the following times?

		Never or rarely	<1 day/week	1 day/week	2 to 3 days/week	4 to 5 days/week
a	Before school	☐	☐	☐	☐	☐
b	Break times	☐	☐	☐	☐	☐
c	During school	☐	☐	☐	☐	☐
d	After school	☐	☐	☐	☐	☐

41. Are teachers or staff members paid to supervise intramural sports or physical activity clubs? ☐ Yes ☐ No

42. Must students pay an activity fee to participate in intramural activities? ☐Yes ☐No

43. Is the fee waived if a student cannot afford to pay? ☐Yes ☐No

General Physical Activity Promotion

44. Weather permitting, approximately what proportion of students walk or bike to school regularly (e.g. at least twice a week)?

☐ None
☐ 20%
☐ 40%
☐ 60%
☐ 80%
☐ 100%

45. Which of the following are barriers to students walking or bicycling to school? (Check all that apply)

- ☐ There are no barriers to students walking or bicycling to school
- ☐ Fearful for personal safety due to crime (i.e. assault, robbery, etc)
- ☐ Lack of sidewalks
- ☐ No secure place for bicycles at school
- ☐ Traffic
- ☐ Weather conditions
- ☐ Distance
- ☐ Other

46. Which of the following practices (what your students and staff are allowed to do on a regular basis) does your school allow?

Students are allowed to . . .	Yes	No
Use indoor physical facilities for recreation outside school hours	☐	☐
Use outdoor physical facilities for recreation outside school hours	☐	☐

47. Do you agree or disagree with the following statements?

	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
a. It is important for school staff to role model physically active behaviors for students	☐	☐	☐	☐	☐
b. Physical activity for students is a priority in this school	☐	☐	☐	☐	☐

48. Below is a list of approaches schools can use to promote physical activity among their students. Do you agree or disagree that your school is doing the following statements?

		Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
a	Encourage walking or cycling to school	☐	☐	☐	☐	☐
b	Initiatives to make it safer for students to walk/cycle to school (e.g. safer road crossing, pedestrian safety program, bike education)	☐	☐	☐	☐	☐
c	Encourage students to be more active outside of school hours	☐	☐	☐	☐	☐
d	Encourage use of equipment and facilities by students during school hours	☐	☐	☐	☐	☐
e	Permitting students to use indoor facilities for physical activity	☐	☐	☐	☐	☐
f	Permitting students to use outdoor facilities for physical activity	☐	☐	☐	☐	☐
g	Permitting community members and organizations to use indoor facilities for physical activity outside school hours	☐	☐	☐	☐	☐
h	Permitting community members and organizations to use indoor facilities for physical activity outside school hours	☐	☐	☐	☐	☐
i	Encouraging staff to be involved in lunchtime activity programs	☐	☐	☐	☐	☐
j	Involving students in decision making regarding physical activity opportunities, equipment and facilities	☐	☐	☐	☐	☐
k	Having regularly scheduled physical activity times during non-PE classes	☐	☐	☐	☐	☐

Questions that may require you to look something up or call someone . . .

49. What percent of students are bused to school? ___ ___ ___ %

50. Does your district provide financial support to the food service program or require it to be self-sustaining?

☐ District provides financial support —–> If so, what percentage of the program's total funding, is provided by the district?

___ ___ ___ %

☐ Required to be self sustaining ———> If so, what is your average daily participation (ADP) in school-sponsored USDA-regulated reimbursable lunch as a percent of enrollment?

___ ___ ___ %

51. On a typical day, about how many students at this school receive . . .

___ Free breakfasts?
___ Reduced-price breakfasts?
___ Paid breakfasts, that is, meals sold at full-price?

52. On a typical day, about how many students at this school receive . . .

___ Free lunches?
___ Reduced-price lunches?
___ Paid lunches, that is, meals sold at full-price?

FOOD SERVICE SURVEY

1. What is your gender? ☐ Male ☐ Female

2. How many years have you served in this position? ____ years

3. What level of education have you completed? *(Check all that apply)*
☐ High school or GED
☐ Associates Degree
☐ Undergraduate Degree, if yes, please specify major:___________________________________
☐ Masters Degree, if yes, please specify area(s):_______________________________________
☐ Doctoral Degree, if yes, please specify area(s):_______________________________________

4. Does your school offer . . .	Yes	No
USDA School Breakfast Program	☐	☐
USDA National School Lunch Program	☐	☐
USDA After School Snack Program	☐	☐
A la carte breakfast	☐	☐
A la carte lunch	☐	☐

5. Do any commercial food vendors (Pizza Hut, Taco Bell, Subway) offer food as part of the lunch service?
☐ Yes——————————————> If yes, what is offered? (*Check all that apply)*
☐ Traditional ("burger and fries") fast food restaurants, such as McDonalds, Burger Kind, Arby's, Wendy's, White Castle
☐ Mexican fast food restaurant, such as Taco Bell, Taco Johns, Chipotle
☐ Fried chicken, such as Kentucky Fried Chicken
☐ Sandwich or sub shop, such as Subway, Panera, Quiznos
☐ Pizza, such as Pizza Hut, Papa Johns, Davannis
☐ No

6. Is food cooked at this school (not just reheated) for students' breakfasts?
☐ Yes ——————————————> 9b. If yes, how often (on average):
☐ Everyday
☐ 3-4 times a week
☐ 2 times a week
☐ 1 time a week
☐ No

7. Is food cooked at this school (not just reheated) for students' lunches?

☐ Yes ——————————————> 10b. If yes, how often (on average):

☐ No

- ☐ Everyday
- ☐ 3-4 times a week
- ☐ 2 times a week
- ☐ 1 time a week

8. What are the conditions of the . . .

	Great	Good	Fair	Poor
a. Kitchen infrastructure (floor, ceiling, plumbing, tables, etc)	☐	☐	☐	☐
b. Kitchen equipment (stoves, refrigerators, mixers, etc)	☐	☐	☐	☐
c. Serving area (warming pans, tables, salad bar, etc)	☐	☐	☐	☐

9. If you could make one improvement to your food service facilities what would they be?

---

10. How do students pay for school meals?

- ☐ Cash
- ☐ Computerized payment system
- ☐ Other, please specify:___________________________

11. How many minutes do students usually have to eat lunch once they are seated? ___ minutes

12. In an average week how many times are the following foods offered?

	Everyday	3-4 days	2 days	1 day	Never
Salad Bar	☐	☐	☐	☐	☐
Whole grains	☐	☐	☐	☐	☐
2 different main courses	☐	☐	☐	☐	☐
2 different vegetables	☐	☐	☐	☐	☐
2 or more fruits or types of 100% fruit juice	☐	☐	☐	☐	☐
Pizza	☐	☐	☐	☐	☐
Deep-fried french fried potatoes, including fries that you just reheat	☐	☐	☐	☐	☐
Spaghetti or other pasta	☐	☐	☐	☐	☐
Cookies, crackers, pastries, cakes, or other baked goods not low in fat	☐	☐	☐	☐	☐
Low-fat cookies, crackers, cakes, pastries, or other low-fat baked goods	☐	☐	☐	☐	☐
Ice cream or frozen yogurt that is not low in fat	☐	☐	☐	☐	☐
Low-fat or fat-free ice cream, frozen yogurt, or sherbet	☐	☐	☐	☐	☐

13. What type of milk is available for students to purchase? (*Check all that apply)*

- ☐ Whole milk
- ☐ Reduced fat milk or 1% milk
- ☐ Skim milk
- ☐ Chocolate whole milk
- ☐ Chocolate reduced fat milk

14. Please fill in the table below, recording the four biggest selling food items and the three biggest selling drinks sold by your school last year:

Four biggest selling foods
1
2
3
4

Three biggest selling drinks
1
2
3

15. Do students serve themselves for . . . (check all that apply)

	Yes	No
Lunch entrees	☐	☐
Lunch sides	☐	☐
A la carte lunch entrees	☐	☐
A la carte lunch sides	☐	☐
Salad bar	☐	☐
Do you use the offer-versus-serve option during lunch?	☐	☐
Are there different portion sizes available to different grade levels?	☐	☐

16. What is the average price of a breakfast meal? $ ___. ___ ___

17. What is the average price of a lunch meal? $ ___. ___ ___

19. On a typical day, about how many students at this school receive . . .

___ Free breakfasts?
___ Reduced-price breakfasts?
___ Paid breakfasts, that is, meals sold at full-price?

20. On a typical day, about how many students at this school receive . . .

___ Free lunches?
___ Reduced-price lunches?
___ Paid lunches, that is, meals sold at full-price?

21. How influential are the following people in making decisions about what food is offered?

		None	A little	Somewhat	A lot	Completely
a	School Food Service Manager	☐	☐	☐	☐	☐
b	District Food Service Manager	☐	☐	☐	☐	☐
c	Food systems company	☐	☐	☐	☐	☐
d	School nutrition/health committee	☐	☐	☐	☐	☐
e	Principal	☐	☐	☐	☐	☐
f	Parents	☐	☐	☐	☐	☐
g	Students	☐	☐	☐	☐	☐

22. Not counting the reheating of prepared foods, which group has primary responsibility for <u>cooking</u> foods for students at this school?

☐ Staff working at the district food service office
☐ School staff
☐ Food service management company staff
☐ Fast food company staff

4 of 6

23. Do you agree or disagree with the following statements about the role of your school's cafeteria?

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Provide a food service	☐	☐	☐	☐	☐
Insure students get enough calories	☐	☐	☐	☐	☐
Insure students don't get too many calories	☐	☐	☐	☐	☐
Make a profit for the food service company	☐	☐	☐	☐	☐
Make a profit for the school needs	☐	☐	☐	☐	☐
Support classroom nutrition education	☐	☐	☐	☐	☐
Provide and promoting healthy food	☐	☐	☐	☐	☐

24. In the last year, did any of the following factors help your school's cafeteria to provide healthier food choices? (*Check all that apply)*

☐ Networking with other schools in the area
☐ Assistance from health professionals
☐ Support from teaching staff
☐ Requests from parents
☐ Training for food service staff
☐ Easy access to healthier food choices
☐ Knowledge of the childhood obesity problem
☐ Special deals on healthier food products
☐ More storage space available
☐ Promotions of healthier food products
☐ Suitable equipment now available
☐ Information from media

25. In the last year, which of the following limited your school's cafeteria from providing more healthy food choices? (Check all that apply)

- ☐ None, already sell plenty of healthy choices
- ☐ Need to make a profit, selling healthier food is less profitable
- ☐ Special deals from distributers for less healthy food
- ☐ Can't get easy access to healthy food products
- ☐ Lack of demand from students
- ☐ Lack of support from parents
- ☐ Lack of support from food service staff
- ☐ Lack of support from school administration
- ☐ Competition with a la carte options
- ☐ Have tried, too much waste
- ☐ Lack of time to prepare, more labor intensive
- ☐ Lack of volunteers (school staff or parents)
- ☐ Healthy food is too expensive to buy for school meals
- ☐ Poor shelf life of fresh food
- ☐ Lack of storage space
- ☐ Lack of suitable equipment, please specify:.______________________________
- ☐ Lack of preparation area
- ☐ Lack of display space

26. Does your district provide financial support to the food service program or require it to be self-sustaining?

☐ District provides financial support ——> If so, what percentage of the program's total funding, is provided by the district?

___ ___ ___ %

☐ Required to be self sustaining ———> If so, what is your average daily participation (ADP) in school-sponsored USDA-regulated reimbursable lunch as a percent of enrollment?

___ ___ ___ %

27. Does your school participate in a farm to school program? ☐ Yes ☐ No

If yes, how many months out of the year is this possible? ___ months
On average during those months, how many times a week will local produce be served? ___/week

28. Does your school have a school garden? ☐ Yes ☐ No

If yes, does the produce from it get used in school lunches? ☐ Yes ☐ No
If yes, how many months out the year is this possible? ___ months
On average during those months, how many times a week does the garden produce served? ___/week

PHYSICAL ACTIVITY SURVEY

1. What is your gender? ☐ Male ☐ Female

2. How many years have you served in this position? ____ years

3. What level of education have you completed? *(Check all that apply)*

☐ High school or GED
☐ Associates Degree
☐ Undergraduate Degree, if yes, please specify major:_______________________________________
☐ Masters Degree, if yes, please specify area(s):____
☐ Doctoral Degree, if yes, please specify area(s):____

4. Do you participate at least once a year in professional development/continuing education in physical education? (*Professional development/continuing education means on-site (e.g. school district) and off-site (e.g. city or state) training opportunities)*

☐ Yes ☐ No

5. Are you the only physical education teacher at this school? ☐ Yes ☐ No

If no, how many other are there? _____ number of other PE teachers at this school

6. Do you have other responsibilities other than being the PE teacher at this school? *(e.g. academic teacher, coach, PE teacher at another school as well)*

☐ Yes ☐ No

If yes, please specify: ____

Questions about Physical Education

7. How many of the following indoor and outdoor facilities are present on school grounds at this school?

Indoor Facilities	Outdoor Facilities
____ Weight training facility	____ Outdoor basketball court
____ Cardiovascular Fitness Center	____ Softball Field
____ Indoor pool	____ Baseball field
____ Multi-purpose room	____ Soccer field
____ Gym	____ Football field
____ Wrestling room	____ Track
____ Dance studio	____ Tennis court
Racquetball court	____ Outdoor pool
	____ Outdoor volleyball court

8. What best describes the student-to-teacher ratio for PE classes at your school?
- ☐ 10-19 students per 1 teacher
- ☐ 20-29 students per 1 teacher
- ☐ 30-39 students per 1 teacher
- ☐ 40+ students per 1 teacher

9. What best describes the student-to-teacher ratio for a majority of other classes at your school?
- ☐ 10-19 students per 1 teacher
- ☐ 20-29 students per 1 teacher
- ☐ 30-39 students per 1 teacher
- ☐ 40+ students per 1 teacher

10. Do students have access to use showers at the end of PE period? ☐ Yes ☐ No

11. Do students have time to use showers during PE period? ☐ Yes ☐ No

12. Do students change into PE clothes for their PE period? ☐ Yes ☐ No

13. Which of the following activities are taught in PE at this school?

☐	Aerobics	☐	Kickball
☐	Badminton	☐	Lacrosse
☐	Baseball, softball, whiffleball	☐	Martial arts
☐	Basketball	☐	Non-stationary bicycling
☐	Bowling	☐	Racquet sports (e.g. racquetball, handball, squash, or paddleball)
☐	Climbing ropes or wall ladders	☐	Skating (e.g. roller, in-line, or ice)
☐	Exercise machines (e.g. rowers, ski machines, stair climbers, stationary bikes, treadmills)	☐	Skiing (e.g. cross country, downhill, or water)
☐	Dance (e.g. ballet, folk, line, square)	☐	Soccer
☐	Dodgeball or bombardment	☐	Student-designed games
☐	Climbing wall	☐	Tennis
☐	Football (e.g. touch or flag)	☐	Track and field
☐	Frisbee or frisbee golf	☐	Ultimate frisbee
☐	Golf	☐	Volleyball
☐	Gymnastics	☐	Walking, jogging, or running
☐	Hiking, backpacking, or orienteering	☐	Weight training
☐	Hockey (e.g. field, floor, roller, or ice)	☐	Wrestling
☐	Jumping rope	☐	None of the above

14. Do you agree or disagree with the following statements about <u>what limits the amount</u> of physical education your school can offer?

	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Not enough time in the school day	☐	☐	☐	☐	☐
Not enough money to support more PE teacher hours	☐	☐	☐	☐	☐
Not enough equipment for students during PE period	☐	☐	☐	☐	☐

15. Does your school have any policies (written procedures or guidelines share with students and staff) regarding whether . . .

		Yes	No
a	Students earn grades for required PE classes?	☐	☐
b	PE grades count the same as other classes?	☐	☐
c	All PE teachers are certified PE specialists?	☐	☐
d	Students can substitute PE classes with other classes (ROTC, band)?	☐	☐

16. Does your school practice any of the following . . .

		Yes	No
a	The use of physical activity as a punishment strategy for inappropriate behavior (making students run laps or do push-ups as a consequence of inappropriate behavior)?	☐	☐
b	Withholding PE class as a punishment strategy?	☐	☐
c	The maximum student-to-teacher ratio for PE classes?	☐	☐
d	The provision of individualized physical activity/fitness plans?	☐	☐

17. How many quarters, trimesters, or semesters per year are students in your middle or junior high school required to take PE?

___ Number of Quarter(s)
___ Number of Trimester(s)
___ Number of Semesters(s)

18. On average, how many minutes of PE per week are required per quarter, trimester, or semester?

___ Minutes per week per quarter, trimester, semester

19. On average, how long is . . .

The total PE period	____ minutes
Time allowed to change clothes	____ minutes
Time spent giving instructions	____ minutes
Time allowed to change back into school clothes	____ minutes

20. Are students moderately to vigorously active at least 50% of the time during most or all physical education class sections?

(*Moderate to vigorously active means engaging in physical activity that is equal in intensity t or more strenuous than fast walking).*

☐ Yes, during every class
☐ During about half of classes
☐ During fewer than half of classes
☐ During none of the classes

Questions about Athletics

21. Which of the following organized physical activities and sports were offered in the school out of school hours (extracurricular)?

		Both Boys and Girls	Only Boys	Only Girls	Neither
A	Badminton	☐	☐	☐	☐
B	Baseball	☐	☐	☐	☐
C	Basketball	☐	☐	☐	☐
D	Bowling	☐	☐	☐	☐
E	Cheerleading or competitive spirits	☐	☐	☐	☐
F	Cross-country	☐	☐	☐	☐
G	Downhill or cross-country skiing	☐	☐	☐	☐
H	Fast pitch or slow pitch softball	☐	☐	☐	☐
I	Field hockey	☐	☐	☐	☐
J	Football	☐	☐	☐	☐
K	Golf	☐	☐	☐	☐
L	Gymnastics	☐	☐	☐	☐
M	Ice hockey	☐	☐	☐	☐
N	Lacrosse	☐	☐	☐	☐
O	Riflery	☐	☐	☐	☐
P	Soccer	☐	☐	☐	☐
Q	Swimming or diving	☐	☐	☐	☐
R	Tennis	☐	☐	☐	☐
S	Track and field	☐	☐	☐	☐
T	Volleyball	☐	☐	☐	☐
U	Water polo	☐	☐	☐	☐
V	Weight lifting	☐	☐	☐	☐
W	Wrestling	☐	☐	☐	☐

22. Must students pay an activity fee to participate in extracurricular physical activities or sports?

☐ Yes —> If yes, is fee waived if student cannot afford to pay? ☐ Yes ☐ No

☐ No

23. To the best of your ability, what percentage of <u>each sex</u> participates in school-sponsored <u>extracurricular</u> physical activity programs?

Boys	Girls
☐ 0 %	☐ 0 %
☐ <10%	☐ <10%
☐ <20%	☐ <20%
☐ <30%	☐ <30%
☐ <40%	☐ <40%
☐ <50%	☐ <50%
☐ <60%	☐ <60%
☐ <70%	☐ <70%
☐ <80%	☐ <80%
☐ <90%	☐ <90%
☐ <100%	☐ <100%

24. To the best of your ability, what percentage of <u>each sex</u> participates in school-sponsored <u>intramural</u> physical activity programs?

Boys	Girls
☐ 0 %	☐ 0 %
☐ <10%	☐ <10%
☐ <20%	☐ <20%
☐ <30%	☐ <30%
☐ <40%	☐ <40%
☐ <50%	☐ <50%
☐ <60%	☐ <60%
☐ <70%	☐ <70%
☐ <80%	☐ <80%
☐ <90%	☐ <90%
☐ <100%	☐ <100%

25. Must students pay an activity fee to participate in intramural activities or physical activity clubs?

☐ Yes —> If yes, is fee waived if student cannot afford to pay? ☐ Yes ☐ No
☐ No

ENVIRONMENTAL CHECKLIST

NUTRITION

Cafeteria

1. Please rate the following for the cafeteria . . .

	Great	Good	Fair	Poor	N/A
Physical structure (e.g. walls, floor covering, does not need repairs)	☐	☐	☐	☐	☐
Tables and chairs (are not damaged and are of appropriate size for all students)	☐	☐	☐	☐	☐
Seating (is not overcrowded i.e. never more than 100% of capacity)	☐	☐	☐	☐	☐
Smells are pleasant and not offensive	☐	☐	☐	☐	☐
General Descriptions and Notes:					

2. Are their advertisements visible for . . .

	Yes	No	Description
Soft drinks	☐	☐	
Commercial foods	☐	☐	
Flyers for fundraisers involving food	☐	☐	
Healthy eating promotion	☐	☐	
Physical activity promotion	☐	☐	

3. Do students serve themselves for . . . (check all that apply)

	Yes	No
Lunch entrees	☐	☐
Lunch sides	☐	☐
A la carte lunch entrees	☐	☐
A la carte lunch sides	☐	☐
Salad bar	☐	☐

☐ Other, please specify:_________________________

4. What are the conditions of . . .

	Great	Good	Fair	Poor
Kitchen infrastructure (floor, ceiling, plumbing, tables, etc)	☐	☐	☐	☐
Kitchen equipment (stoves, refrigerators, mixers, etc)	☐	☐	☐	☐
Serving area (warming pans, tables, salad bar, etc)	☐	☐	☐	☐

5. Sketch of food service area

Vending Machines

6.

Location*	Drink or food (D or F)	Pricing of Items	Items available
1.			
2.			
3.			
4.			
* C= cafeteria, H= hallway, N= near gym, O= outside, D= near main door *(use all that apply)* ** B= bottom, E= eyelevel, U= upper			

School Snack Bar

7. The school snack bar offers . . . *(check all that apply)*

- ☐ Regular sodas (12oz cans)
- ☐ Regular sodas (20 oz bottles)
- ☐ Diet sodas (12oz cans)
- ☐ Diet sodas (20 oz bottles)
- ☐ Fruit drinks (less than 50% fruit juice)
- ☐ Fruit drinks (at least 50% fruit juice)
- ☐ Water
- ☐ Ice tea (sweetened)
- ☐ Ice tea (unsweetened)
- ☐ Other snacks, please specify:______________________________
- ☐ Candy
- ☐ Chips
- ☐ Crackers
- ☐ Cookies
- ☐ Sandwiches
- ☐ Fresh fruit
- ☐ Baked goods
- ☐ Granola bars
- ☐ Trail Mix

Advertisements

8. Are their advertisements visible for . . .

	Yes	No	Description
Soft drinks	☐	☐	
Commercial foods	☐	☐	
Flyers for fundraisers involving food	☐	☐	
Healthy eating promotion	☐	☐	
Physical activity promotion	☐	☐	

Active Transport and Nature

9. The following are present on the campus:

	Yes	No
Bike racks	☐	☐
Sidewalks on school premises	☐	☐
Sidewalks that lead off of school premises	☐	☐
Trails around school	☐	☐
Wooded areas that student have access to	☐	☐
Windows in classroom	☐	☐

10. Sketch any food stores/restaurants around the school

APPENDIX F: Consent form for school assessment

I am asking you to participate in a research study. This form is designed to give you information about this study. I will describe this study to you and answer any of your questions.

Project Title: *Children of the Women in the First Bassett Mothers Health Project*

Principal Investigator: *Margaret Demment*
Nutritional Sciences
mmd238@cornell.edu
518.867.5225

Faculty Advisor *(if PI is a student)*: *Christine Olson, PhD*
Nutritional Sciences
cmo3@cornell.edu
607.255.2634

What the study is about

Rural children are at greater risk for overweight and obesity than urban children. This study is interested in improving the health of rural adolescents. Your answers will help us better understand how middle schools are improving or maintaining student health.

What we will ask you to do

I will ask you to spend 5-15 minutes filling out this questionnaire about aspects of your school's food and physical activity environment.

Risks and discomforts

The answer will be used for research purposes only and your name will not be connected to them at all. We do not anticipate any risks to you from participating other than those encountered in daily life.

Benefits

There are no direct benefits or compensation to the participant. However, information from this study will be used to more about adolescent health in rural communities.

Privacy/Confidentiality

All data will be entered into a password-protected computer with each school given a ID number. No identifiable markers will be recorded with the data that would allow information about the school to be traced back to a particular school or person within the school.

Taking part is voluntary

Participation in this questionnaire is voluntary, you may refuse to participate before the study begins, discontinue at any time, or skip any questions/procedures that may make him/her feel uncomfortable, with no penalty to you.

If you have questions

The main researcher conducting this study is ***Margaret Demment,*** a *graduate student* at Cornell University. Please ask any questions you have now. If you have questions later, you may contact *Margaret* at ***mmd238@cornell.edu*** or at ***518.867.5225***. If you have any questions or concerns regarding your rights as a subject in this study, you may contact the Institutional Review Board (IRB) for Human Participants at 607-255-5138 or access their website at http://www.irb.cornell.edu. You may also report your concerns or complaints anonymously through Ethicspoint online at www.hotline.cornell.edu or by calling toll free at 1-866-293-3077. Ethicspoint is an independent organization that serves as a liaison between the University and the person bringing the complaint so that anonymity can be ensured.

You will be given a copy of this form to keep for your records.

Statement of Consent

I have read the above information, and have received answers to any questions I asked. I consent to take part in the study.

Your Signature____ Date____________

Your Name (printed)____

Signature of person obtaining consent______________________________ Date____________

Printed name of person obtaining consent____

This consent form will be kept by the researcher for at least five years beyond the end of the study and was approved by Cornell University's Institutional Review Board for Human Participants on:

Approved By:

Approval Date   Expiration Date

19 JUL 2011 to **18 JUL 2012**

Cornell University
Institutional Review Board