SOCIO-ENVIRONMENTAL FACTORS ASSOCIATED WITH DIETARY OUTCOMES AMONG U.S. PARENT-ADOLESCENT DYADS: A CROSS-SECTIONAL STUDY

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Science

by

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August 2025

ABSTRACT

Background: Consumption of ultra-processed foods is increasing in the United States (U.S.), compromising diet quality and its associated risk with cardiometabolic diseases. The Socio-Ecological Model provides a framework for understanding factors that may be associated with dietary outcomes, and current evidence is mixed regarding the association between these factors and dietary outcomes. Due to our limited understanding about this relationship, particularly within the family context, this study examines the association between socio-environmental factors and dietary outcomes in U.S. parent-adolescent dyads.

Purpose: This study examines interdependent associations between socio-environmental factors and consumption of nutrient-dense foods (NDF) and ultra-processed foods (UPF) in a demographically representative sample of U.S. parents and adolescents.

Methods: Parent-adolescent dyads enrolled in the Family Life, Activity, Sun, Health, and Eating (FLASHE) study were each administered online surveys about their diet and potential related factors. Parent-adolescent dyads (n=1,850) completed questio used for analyses, while the sample size was reduced to a total of 1,581 dyads in the final models. Multilevel linear regressions were used to test study hypotheses.

Results: Results from standardized multilevel linear regression tests revealed that different combinations of socio-environmental factors are associated with parent-adolescent NDF and UPF consumption. Among significant factors, NDF consumption correlated positively with the type of stores visited by the parent to purchase food

(β_p=0.66, p=0.000; β_a=0.50, p=0.000), with a greater effect on parents ($\Delta\beta$=0.16, p=0.041), NDF consumption also correlated negatively with eating behavior away from the home (β_p=-0.17, p=0.036; β_a=-0.59, p=0.000), with a greater effect on adolescents ($\Delta\beta$=-0.42, p=0.000). Regarding UPF consumption, findings suggest a negative correlation with food availability in the home (β_p=-0.67, p=0.000; β_a=-0.90, p=0.000), with a greater effect on adolescents ($\Delta\beta$=-0.23, p=0.005). The conditional effect of adolescents given average scores on continuous measures associated with UPF consumption ($\Delta\beta$=1.00, p=0.000) was significant.

Conclusions and Implications: Household-level factors were stronger predictors of dietary outcomes compared to other socio-environmental influences at neighborhood levels (i.e., school). In adjusted models, adolescents consumed more UPF than parents, suggesting the presence of additional adolescent-specific factors that need further research. Interventions in the home environment that aim to reduce UPF and improve NDF intake are warranted.

BIOGRAPHICAL SKETCH

Qingyu Shao is a second-year community nutrition student in the Department of Nutritional Sciences under the College of Human Ecology at Cornell University. She received a Bachelor of Science degree in Nutritional Sciences from Cornell University in 2023. She also recently graduated from Cornell University's Dietetic Internship in May 2025.

ACKNOWLEDGMENTS

This work is the final milestone in my six years of learning at Cornell University. As I reflect on this memorable period, I am grateful for everything that I was able to experience during this time. The faculty in the Department of Nutritional Sciences have supported me in my learning throughout the past six years. My special thanks are extended to Professor Roger Figueroa Bautista for his trust and constant support in my academic progress. His input, and that of Professor Tashara Marie Leak, were integral during the preparation of this thesis. Professors Erin Marie Green, Emily Wilcox Gier, Kelly Quinn, and Laura Bellows were also crucial supporters in my academic journey. I would like to thank the compassionate upper-class graduate students in the Figueroa Interdisciplinary Group and in the Department of Nutritional Sciences, namely Ruyu Liu, Reah Chiong, and Shariwa Oke, who allowed me to conduct research with them and learn alongside them. I also extent my thanks to Kenneth Tyler Wilcox at the Cornell Statistical Consulting Unit for his patience and support in constructing the statistical methodology of this thesis.

Many others provided life inspiration that encouraged me to continue moving forward. I would like to thank the past and current members of Yamatai Taiko ("Taiko at Cornell") for brightening my time at Cornell with friendship and the joy of creating music together. I would also like to thank the former and current English department chairs James Bair and Benjamin Chase at Christian Heritage School in Trumbull, CT for showing me the beauty and impact of words and language.

Most of all, I wish to thank my parents, Yanfang Wang and Chuanjing Shao, for their unwavering support in everything that I do.

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INTRODUCTION

Over half of adults in the United States (U.S.) are diagnosed with at least one chronic health condition,[1] and disease prevalence has been increasing over the past two decades.[2] The consumption of ultra-processed foods (UPF) is a main contributor to this issue, as strong evidence links UPF consumption with poor dietary quality,[3] increased energy intake and weight gain,[4] elevated risk for chronic diseases including type 2 diabetes and cardiovascular diseases,[5–8] as well as all-cause mortality.[9,10] While the Dietary Guidelines for Americans (DGAs)[11] developed by the U.S. Department of Agriculture provide guidelines for health promotion and disease prevention through dietary intake, adherence to the DGAs remains low,[12] and UPF now accounts for more than 50% of daily caloric intake across the U.S. population.[13,14] Both adults and adolescents are failing to meet the recommendations for fruits, vegetables, and other key components including whole grains and essential micronutrients.[12,15,16] The DGAs place emphasis on the consumption of fruits, vegetables, beans, whole grains, and lean protein, which could be categorized as nutrient dense foods (NDF). NDF are defined as food that is high in nutrients but relatively low in calories, while containing vitamins, minerals, complex carbohydrates, lean protein, and healthy fats.[17] The DGAs also encourage the limitation of foods rich in added sugars, sodium, and saturated fat, which are characteristics of ultra-processed foods (UPF). UPF are defined using the NOVA classification system as industrially formulated foods high in additives and

substances of rare culinary use.[18] Encouraging individuals to increase NDF intake and reduce UPF consumption concurrently may be key to improving the general health of Americans.

Alarmingly, U.S. adolescents now derive over two-thirds of their daily calories from UPF, while their consumption of NDF decreases.[19] Since dietary habits established during childhood and adolescence would continue into adulthood,[20,21] it is crucial to establish dietary patterns in adolescence that would set the foundation for a healthy life. Parents play a central role in shaping adolescents' dietary choices, through mechanisms such as modeling, food availability, and household routines.[22] It is unsurprising that parent and adolescent dietary patterns are found to be significantly correlated,[23,24] but research also highlights bidirectional influences, that adolescents also affect the family's food practices.[25] Given their shared environments and interdependent decision-making, it is critical to examine dietary intake in the context of the parent–adolescent dyad to inform public health programs that aim to improve health through dietary components.

However, despite many public health efforts to promote healthier dietary patterns among adults and adolescents, many nutrition interventions in the U.S. have shown limited success.[26–29] School-based interventions aimed at reducing UPF consumption have similarly yielded only modest effects and also fall short of improving long-term diet quality,[30,31] which calls for the implementation of systems-based strategies.[32] The Academy of Nutrition and Dietetics has emphasized that

interventions should use a systems-level approach that considers family, environmental, and policy level determinants simultaneously as a more comprehensive approach.[33] Without this systems-level understanding, interventions may remain misaligned with the complex layers of factors that influence the consumption of NDF and UPF.

Indeed, food choice is complex and multifaceted as it occurs in the context of multilevel factors.[34] The Socio-Ecological Model provides a lens through which dietary behaviors are related to factors across individual, family, community, and policy levels.[35] Numerous studies have identified socio-ecological factors associated with dietary intake, but results are wide-ranging. Systematic review evidence reveals inconsistent associations between socioeconomic status, neighborhood food environments, and diet quality of adults and adolescents across different populations and contexts.[36–38] This variability may stem from the lack of consideration for interactions between factors across various levels of influence. As such, a systems-level approach can elucidate on the complex nature of UPF and NDF consumption as influenced by multiple socio-environmental determinants simultaneously. While much of the existing literature tends to assess socio-environmental factors as individual predictors of dietary outcomes, there remains opportunity to account for the interdependent nature of these associations at the population level, and in turn also better inform interventions and policy.[39]

To address current knowledge gaps in the association between socio-environmental factors influencing UPF and NDF intake, the current study utilizes multilevel modeling to simultaneously assess these factors while also accounting for clustered nature of parent-adolescent relationships within the household. The aim of this study was to examine the interdependent association between socio-environmental factors on UPF and NDF intake among parent-adolescent dyads. This study seeks to offer new insights into which factors are most significantly associated with dietary outcomes within the family context to inform public health strategies for adolescents and their families.

LITERATURE REVIEW

Introduction

Over half of adults (51.8%) in the United States (U.S.) are diagnosed with at least one chronic health condition such as heart disease, diabetes, and cancer,[1] with disease prevalence increasing over the past two decades and still expected to continue growing.[2,40] The consumption of ultra-processed foods (UPF) is a main contributor to this issue, as a growing body of evidence has linked higher UPF consumption to increased risks of cardiometabolic diseases and all-cause mortality.[9,41,42] UPF consumption has grown steadily and now accounting for more than 50% of daily caloric intake across the U.S. population.[13,14] This trend is not unique to individuals with chronic illnesses but extends to those without pre-existing conditions, indicating a widespread dietary shift towards higher UPF consumption.[43] Alarmingly, these dietary patterns are also common among U.S. youths, who now derive over two-thirds of their total daily caloric intake from ultra-processed sources while consumption of minimally processed foods decreases.[19]

Adolescence is a critical developmental period for shaping lifelong dietary habits, as behaviors established in this stage are often sustained into adulthood and influence long-term health outcomes.[20] While this life stage is marked by increasing autonomy in food choices,[44] parents remain as a central role shaping adolescents' dietary choices, through mechanisms such as modeling, home food availability, and household food practices.[22,44] Studies have shown that there are significant dietary

similarities within parent–adolescent dyads.[23] Moreover, emerging research also highlights bidirectional influence, suggesting that adolescents' preferences and autonomy can influence family food practices.[45,46] Thus, understanding dietary behaviors in the context of the parent–adolescent dyads is essential, especially when considering the clustered nature of parent-adolescent relationships.

Despite public health efforts to improve diet quality, most interventions aimed at reducing UPF intake have not demonstrated effectiveness in both adults and adolescents.[28] Educational and behavioral interventions frequently improve knowledge but fail to translate into lasting dietary changes.[26,29] School-based interventions targeting UPF have produced only modest effects and also fall short of improving long-term diet quality.[30,31] Even community and culturally tailored programs demonstrate only limited success.[27] This lack of sustained, meaningful changes in dietary outcomes highlight the need for a more comprehensive lens through which we can tackle UPF consumption.

The Socio-Ecological Model is a theoretical framework that recognizes that health is affected by multiple levels of influence, ranging from individual to family, organizational, community, and policy levels.[35] In the context of dietary behavior, the Socio-Ecological Model illustrates the importance of considering not only individual choices but also broader social and environmental determinants that shape food access, routines, and beliefs. Despite this theoretical foundation for considering multilevel influences, their complexity often leads to mixed empirical evidence when

studying dietary outcomes. Systematic reviews have documented inconsistent associations between socioeconomic status (SES), neighborhood food environments, and diet quality across various populations. For instance, while neighborhood access to healthy food retailers was associated with diet quality in some U.S. communities, the relationship was not consistent across income groups,[36] and there are also varying associations between SES and food purchasing behaviors across urban and rural settings.[37] These inconsistencies suggest that as dietary behaviors are shaped by a complex web of interacting influences, understanding what drives UPF consumption and nutrient-dense food (NDF) intake requires moving beyond isolated predictors to examine multiple socio-environmental factors in one system,[38] including the dynamic interplay between personal, household, and environmental contexts.[34] Therefore, this review synthesizes current evidence on socio-environmental factors across multiple levels that are highlighted in the Socio-Ecological Model to build the rationale for using a systems-level approach to investigate factors that may affect UPF and NDF intake.

This thesis seeks to partially assess the complexity of ecological factors that drive dietary intake of UPF and NDF among U.S. parent-adolescent dyads. Few studies have investigated multi-level socio-environmental factors within parent–adolescent dyads, despite evidence that dietary behaviors are shaped by both shared environments and reciprocal influences within households.[47,48] Using data from the National Cancer Institute (NCI)'s Family Life, Activity, Sun, Health, and Eating

(FLASHE) study,[49] this study adopts a systems-level approach to examine the socio-environmental determinants of UPF and NDF consumption among U.S. parent–adolescent dyads. This study aims to identify which factors in the context of a system of socio-environmental factors are strongly associated with dietary intake in the hopes to inform more effective dietary interventions.

Theoretical Framework

The Socio-Ecological Model[35] is commonly used to guide the theoretical framework of studies that investigate the association of individual behaviors and surrounding social factors. The Socio-Ecological Model conceptualizes health behaviors as the product of interactions across multiple levels: individual, interpersonal, organizational, community, and policy.[35] At the individual level, factors include income, knowledge and attitudes. Interpersonal factors encompass family dynamics, such as parental influence over food purchasing and meal preparation. Community-level factors include access to grocery stores and fast-food outlets near homes or schools, while policy-level influences reflect national regulations around food labeling, marketing, and subsidies for ultra-processed foods.[50] This framework highlights the necessity of examining dietary behaviors within a multilevel system. However, studies often adapt this framework to reflect available data, frequently focusing on individual, household, and community levels while omitting policy-level factors when such variables are not measured.[45,51,52] This study adopts a similarly

adapted framework, and policy-level factors are not addressed in the main analysis given the scope of available data. Nonetheless, this theoretical grounding supports the current study's systems-level approach to modeling interdependent influences on diet among U.S. parent–adolescent dyads.

Current Evidence

Individual Level Factors

Weight Status. Literature examining the relationship between weight status and dietary behaviors reveals a nuanced and sometimes inconsistent picture, with evidence for both associations and non-associations depending on study design, dietary measure, and analytic approach. Weight status is typically measured via body mass index (BMI). Ample research analyzing dietary patterns indicates that greater adherence to dietary patterns that are high fruit and non-starchy vegetables correlate with lower adiposity and BMI,[53–56] and that diets high in UPF are associated with high BMI.[4,14,57] However, some studies also provide evidence for non-associations. A cohort study with adolescents in Minnesota observed that breakfast frequency, fast-food intake, and sugar-sweetened beverage consumption predicted BMI cross-sectionally but not longitudinally after adjusting for activity and energy intake.[58] This lack of consistent association is also demonstrated in a systematic review.[59]

Weight status influences dietary behavior in the context of stigma. Negative attitudes and discriminatory behaviors toward higher body weight pose psychological

implications that affect dietary outcomes. An experimental study has demonstrated that exposure to weight-stigmatizing cues leads to increased food intake, duration of binge eating episodes, and reduced inhibitory control.[60] Reviews have found that stigmatizing experiences are associated with elevated physiological stress markers, depression, anxiety, and disordered eating in adults and adolescents.[61–63] More specifically, experiences of stigma within families, schools, and healthcare settings contribute to unhealthy coping behaviors such as binge eating and can exacerbate weight gain over time.[64–66]

Individual-level interventions that aim to address weight loss through dietary behaviors show only modest effects. A systematic review of U.S.-based behavioral weight loss trials found that even intensive interventions resulted in only small increases in Healthy Eating Index (HEI) scores, despite constant efforts to shift dietary intake toward national recommendations.[67] Individual characteristics such as food preferences, habits, and beliefs about nutrition also shape dietary intake and further complicate the process of implementing dietary changes. In a randomized controlled trial, participants often overestimate the extent of their dietary improvements, and their perceived increases in diet quality were significantly greater than what was reflected in HEI scores, pointing to a gap between individual intention and actual dietary outcomes.[68] It is necessary to move beyond the individual perspective and consider the broader social and environmental influences that shape an individual's dietary intake.

Family Level Factors

Parent-Adolescent Dyads. Dietary intake in adolescence sets the foundation for a healthy life, and healthy dietary habits established during childhood and adolescence would moderately continue into adulthood,[20,21] thus highlighting adolescent dietary behaviors and early establishments of healthy-eating as a key public health considerations. Adolescent dietary behaviors are found to be highly contextual and linked to traditional roles of the food environment.[69] A recent systematic review of qualitative studies about the correlates of adolescents' eating behaviors found parents' influence, socioeconomic position, school food environment, neighborhood food environment, household food environment, food insecurity, and availability and affordability of UPF to be factors that influence an adolescent's diet.[70] Another umbrella review identified that parents' influence is a significant correlate of fruit, vegetable, and snack consumption in adolescents, as parents act as gatekeepers of the home food supply and also influence their children's dietary behavior through parenting and modeling.[47]

Examining the dyadic relationship between the parent and the adolescent is a potential pathway for understanding adolescent behavior. Cross-sectional studies with parent-adolescent dyads have identified that parent and adolescent intakes of sugar-sweetened beverages, fruits and vegetables, and convenience and fast-foods are all correlated.[23,71,72] Further, in a study that looked at the diet of adolescents with Type-I diabetes through 136 parent-adolescent dyads, there was a resemblance between

parent and adolescent diet quality without any moderating effect from family meal frequency, suggesting that the resemblance in diet quality is not contingent on having shared meals.[73] Multiple studies have found close associations between parents' health behaviors and their adolescents' health behaviors, including dietary patterns.[74,75] More specifically, parents influence their adolescents' intake through the availability of foods, expectations for intake, and beliefs about health.[74–76] These findings reinforce the importance of examining behavioral associations within family units.

Household Level Factors

Socioeconomic Status: Education, Income, and Food Insecurity.

Socioeconomic status (SES) is a multidimensional construct that shapes dietary behavior through material, behavioral, and psychosocial pathways. While often used as a broad concept, SES is represented in this thesis through three interrelated indicators: parental education attainment, household income, and food security status. Each factor influences the quality and composition of diets in both parents and adolescents, contributing to disparities in nutritional intake and health outcomes.

Educational attainment plays an influential role in shaping food-related knowledge, skills, and preferences. Current research shows that education is a relatively consistent and strong predictor of dietary quality and food-related behaviors across U.S. populations, influencing both individual adults and parent–adolescent dynamics. Studies show that higher education level is associated with higher overall

diet quality, including higher fruit, vegetable, fish, and nutrient diversity, while lower education level is associated with lower diet quality, including higher intakes of carbohydrates, sweets, and red meats.[77–79] Parents' education also has a profound impact on children's dietary outcomes. Studies revealed that adolescents with parents who received higher levels of education reported higher frequency of fruit, vegetable, and dairy consumption,[80,81] and that adolescents whose parents had an education level of high school or less had lesser intakes of fruit, vegetable, and fiber.[82]

Household income determines what food options are economically accessible and which nutritional tradeoffs families are forced to make. Lower-income households tend to have diets that are more energy-dense and nutrient-poor, while higher-income households more often meet dietary guidelines and consume more nutrient-dense foods. Studies using nationally representative U.S. data have consistently found that higher income is associated with better dietary quality, characterized by greater intake of fruits and vegetables with lower intake of frozen desserts.[83] In contrast, households with lower income face greater financial constraints in purchasing NDF as higher-quality diets are associated with higher costs.[84] Research has demonstrated that even small increases in food budget among low-income households can significantly improve adherence to the Dietary Guidelines for Americans.[85] Income is thus a determinant that sets the baseline for what dietary choices are materially possible.

Food insecurity is defined by the USDA as "the limited or uncertain availability of nutritionally adequate and safe foods, or limited or uncertain ability to

acquire acceptable foods in socially acceptable ways."[86,87] Food insecurity has been found to be associated with lower diet quality as well as lower availability and accessibility of healthy foods. A cross-sectional study with a nationally representative sample of more than 3,900 U.S. households found that food secure, non-SNAP households had a higher HEI than food insecure, SNAP-participating households.[88] For adolescents, studies found that food insecurity is associated with less consumption of vegetables and whole grains, higher consumption of sugar-sweetened beverages, more frequent eating at fast-food restaurants, and lower home availability of healthy foods, as well as lower perceived access to affordable fresh fruits and vegetables.[89,90] Moreover, residing in a food desert was found to be associated with a higher child BMI percentile if the child's household was food insecure.[90] A systematic review of food insecurity and diet quality of U.S. parents and children found that food insecurity is associated with lower diet quality in adults but less consistently associated with lower diet quality in children, suggesting that parents shield their children from compromised diet quality.[91]

Although lower SES status has been associated with obesity, low diet quality, and other negative health consequences, interventions to address these outcomes remain variable in effectiveness. A review found that results from nutrition support interventional studies have mostly yielded mixed results, and the authors concluded that it is presently unclear how to best help food insecure individuals improve their diet and weight.[92] A more recent study examined factors that influence the outcome of

an adolescent obesity intervention that included guidance on improving the home food environment and diet quality. The study found that while energy intake and BMI decreased for adolescents regardless of household food security status as a result of the intervention, a reduced obesogenic home food environment and improved diet quality were only observed for food secure households and not insecure households.[93]

These mixed findings strengthen the need for research to consider dietary behavior using a multi-level approach. A recent scoping review aimed to identify the contributing household factors to dietary quality and food security in low-income U.S. households of school-aged children between the ages of 5 to 19 years and found 5 interrelated themes: parental behaviors, child/adolescent behaviors, food procurement behaviors, food preparation behaviors, and household environment factors,[94] indicating that a systems-level approach is necessary to understand the interrelationships of these factors.

Food Purchasing. Choice of food retail venue, including convenience stores, supermarkets, farmers' markets, and discount warehouses, is a key determinant of diet quality and nutritional outcomes in U.S. research. Studies that analyzed data from USDA's nationally representative Food Acquisitions and Purchase Survey (FoodAPS) found that shopping trips to conventional supermarkets and discount stores were linked to higher diet quality as measured by HEI component scores compared to trips to convenience and corner stores.[95,96] Particularly for adolescents, analysis of

NHANES data found that adolescents are more likely to consume beverages, snacks, and sweets from convenience stores than grains, protein, fruits, and dairy from supermarkets.[97] Shopping at warehouse club or discount superstores produced similar scores to conventional supermarkets for the majority of HEI categories,[95] but the same study also found that shoppers with less than some college education and from households participating in SNAP had significantly lower HEI, indicating that SES may have a moderating effect. There seems to be limited research about the association of shopping at farmers markets and community supported agriculture with diet quality using nationally representative samples. However, a study conducted in rural upstate New York found that frequent visits to farmers' markets or farm stands were associated with higher fruit and vegetable intake, and frequent visits to convenience stores were associated with lower intake.[98] Similarly, a cross-sectional study conducted in North Carolina and Kentucky identified that fruit and vegetable consumption was positively associated with use of farmers' markets. Another study with SNAP participants in North Carolina also found that fruit and vegetable consumption was positively associated with farmers' market shopping.[99] While studies about the choice of food outlets generally demonstrate that it is associated with dietary outcomes, the emergence of other socio-environmental factors as moderators indicate the need for a more comprehensive analysis.

Eating Away from Home. Eating away from home—at fast-food restaurants, full-service restaurants, and convenience stores—is strongly linked to worse diet quality and higher calorie intake in the United States, for both adults and adolescents. Regardless of whether restaurants are full-service or fast-food, quality of food generally remains low in both,[100] and consumption of either restaurant foods are associated with increased caloric intake.[101] Studies found that individuals consuming fast food at least once daily had significantly higher total and saturated fat intake, energy density, a lower micronutrient density of meals, and lower diet quality.[102–104] Analysis of NHANES data revealed that 26% of adults consumed a food or beverage obtained from a convenience store on any given day.[105] Moreover, among consumers of food and beverages from convenience stores, 20% of daily energy intake came from convenience store items, with the majority of energy from these items consumed during snack occasions.[105] Analysis of FoodAPS provided similar results, that larger food budget shares at convenience stores and restaurants are linked with poor diet quality based on HEI.[96] Another study that analyzed data from a nationally representative sample of the U.S. found that eating away from home at convenience stores was associated with higher parent and adolescent intakes of added sugars.[106] Despite these associations, it is worth noting that disparities in nutrition of meals consumed at restaurants appear to be worsened by income and education,[100,101] indicating that other factors play a role in influencing food selection and diet quality when eating away from home at restaurants or convenience stores.

Eating in the Home. How meals are prepared and brought into the household also influences the intake of UPF and nutrient-dense food for parents and adolescents. NHANES data show that more frequently having meals prepared away from home was associated with lower intake of vegetables and poorer diet quality among both adults and adolescents.[107,108] Similarly, another study using a nationally representative sample of the U.S. found that in adolescents, fast food eaten at home and heat-and-serve evening meals were associated with lower intake of fruits and vegetables.[109] Contrastingly, cooking at home is associated with lower intake of UPF, higher intake of fruits and vegetables, and better overall diet quality, [106,110–112] though the association between cooking at home and better diet quality is stronger among those with higher income.[112]

Even more nuances exist within these trends based on household income. In one of the studies using NHANES data, it was found that adults in households cooking 7 or more times per week were more likely to have lower education, lower household income, and low food security status; although greater cooking frequency was associated with higher HEI score overall, in households in which dinner was cooked 7 or more times per week, HEI scores differed significantly based on income status.[110] Similarly, in an analysis of Non-Hispanic Blacks, HEI scores were associated with higher cooking frequency for middle income, but not higher or lower income

categories.[113] These findings continue to demonstrate that dietary behaviors are influenced by socio-environmental factors interdependently.

Availability of Foods in the Home. Research consistently demonstrates that the availability and variety of foods at home are strong predictors of household dietary quality. A cross-sectional study with a nationally representative sample of U.S. adults found that the availability of a variety of fruits and vegetables at home were strongly associated with meeting recommended fruit and vegetable intake guidelines as well as lower rates of obesity, while the availability of salty snacks, sweets, and less-healthy beverages were associated with percent energy from fat.[114] As for adolescents, studies found that home availability of fruits and vegetables is a key determinant for fruit and vegetable intake among children and adolescents, and the availability of less nutritious foods in the home has also been associated with undesirable food choices. [75,115–117] Another study examining 2,383 parent-adolescent dyads of parents and adolescents found that healthy home food availability was positively associated with fruit/vegetable intake and negatively associated with soda and snack food intake in adolescents.[118] Despite these findings, the association may be more nuanced for adolescents. In a systematic review with predominantly U.S. research, in the eight studies reported on adolescents aged 10–18 years, half of these studies found a positive association while the other half presented null results. These mixed results

demonstrate the necessity for more comprehensive analyses of adolescent dietary behaviors.

Home Food Environment. Research examining the association between neighborhood food environments and dietary intake in the U.S. has yielded mixed findings. While some studies suggest proximity to certain types of food retailers may influence eating patterns, others emphasize that broader social and behavioral contexts often mediate or moderate these associations.

Several studies using nationally representative or large regional U.S. samples report limited or inconsistent associations between the availability of food retailers near the home and actual dietary intake. One study with 204 parent-adolescent dyads found that for adolescents, convenience stores in the home environment were associated with NDF consumption, while fast food stores were associated with sugar-sweetened beverage consumption.[119] However, a large study of over 97,000 California adults found no strong association between food outlets within 1 mile of home and BMI or dietary intake, including fruit, vegetable, sugar-sweetened beverage, and fast food consumption.[120] Another study in Seattle also found that fruit and vegetable consumption was not associated with physical distance from supermarkets.[121] Moreover, multiple studies have shown that the addition of supermarkets is not associated with improved diet quality of residents in the neighborhood.[122–124]

SES seems to be a moderator of these associations. A study examined the association between neighborhood convenience stores and diet outcomes for 20 years for young adults between ages of 18-30 and found that greater availability of neighborhood convenience stores was associated with lower diet quality for participants that had lower individual-level income, and associations at higher individual-level income were weaker.[125] A longitudinal study in New Jersey investigated the association between changes in food environment and changes in BMI of adults and found that an increase in the number of small grocery stores near the home was associated with a decrease in BMI, while an increase in the number of fast-food restaurants was associated with an increase in BMI, but only for the socially-disadvantaged group.[126]

Some research has tried to investigate the complexity in the association between neighborhood food environments and dietary intake. For example, a study with 12 to 13-year-olds found that the availability of supermarkets and convenience stores in the neighborhood was not associated with where families shop for food or children's dietary behaviors, and that the type of store that families shop at was not associated with the healthiness of food available at home. However, the healthiness of food available at home was associated with healthy dietary behaviors, and eating at fast food outlets and restaurants was associated with unhealthy dietary behaviors in children.[127] The authors of this study interpreted their findings as that focusing only on the home food environment may ignore other important factors that influence young

adolescents' diet outcomes, and this once again points towards the direction of considering multiple structural factors collectively to understand dietary behavior outcomes.

Community Level Factors

School Food Environment and Availability. The food environment surrounding schools, specifically the density and proximity of fast food restaurants, convenience stores, and other outlets, is increasingly recognized as a factor that can influence adolescents' dietary choices and weight outcomes. However, similar to the factor of the home food environment, results are sometimes mixed and may be influenced by other factors.

The presence of unhealthy food retailers near schools may create an "obesogenic" environment that encourages high-calorie, nutrient-poor food consumption. Several studies from the U.S. have demonstrated that the type of food outlet nearest to a school is associated with students' obesity risk. In a study with over 500,000 Californian youths, it was found that adolescents attending schools within 0.5 miles of a fast food restaurant consumed more soda, fewer fruits and vegetables, and were more likely to eat fast food than students without fast food outlets nearby.[128] Similarly, in a large study of over 1 million New York City public high school students, adolescents were more likely to be obese when the closest food outlet to their school was a corner store, regardless of the presence of other food options nearby.[129]

Some research has explored the potential positive impact of healthy food outlets near schools, but results seem ambiguous. In a study in New Jersey with over 13,000 middle and high school students, proximity of the school to small grocery stores that offered some nutrient-dense options and supermarkets was associated with healthier student weight status and a lower probability of being obese.[130] However, not all studies find clear benefits from supermarket proximity. The study with Californian youths mentioned above found no significant association between grocery store proximity and diet quality.[128] Another study based in California also identified no robust relationship between the food environment surrounding schools and the adolescents' consumption.[131]

Although the proximity of food outlets near schools could be considered a factor that could be measured objectively, and the frequency of visiting them could be considered a behavioral factor, few studies to date have explicitly examined the association between dietary intake of adolescents and the frequency of visiting various food outlets within walking distance from the school. This could be that most studies focus on the frequency of visiting these outlets regardless of their distance to the school, or that the neighborhood surrounding the school and the home share the same characteristics. While individual study findings vary, the broader body of evidence indicates that proximity to fast food and convenience stores near schools is generally associated with less healthy dietary patterns in adolescents. Comparatively, the impact of supermarket proximity on diet is more mixed and may depend on other factors.

Policy Level Factors

Advertisements. Emerging evidence demonstrates that the influence of food advertising on dietary behavior reflects in both parents and adolescents. Exposure and attitudes to marketing, especially for UPF, shapes beliefs and consumption patterns across both groups.

The influence of food advertising on dietary behavior is well-examined in literature, particularly among adolescents. Susceptibility to advertisements was identified in cross-sectional studies to be a strong predictor of adolescent sugar-sweetened beverage preference and consumption.[132,133] Meta-analysis also identified moderate evidence that unhealthy food and beverage marketing increases dietary intake and preference for energy-dense, low-nutrition food and beverage.[134] Another systematic review also found strong evidence that food marketing exposure is associated with childhood obesity.[135] As for adults, a recent study analyzing data from a nationally representative sample of the U.S. found that adults who reported positive attitudes toward food advertising consumed more energy-dense, nutrient-poor foods, especially among racial/ethnic minorities.[136]

Parents' influences on their adolescents are shown in research in different ways. Another study using data from the same nationally representative sample of the U.S. found that positive perceptions and trust in food advertisements were significantly associated with increased daily consumption of UPF in both parents and

adolescents. Notably, parents' beliefs about advertisements were also associated with their children's dietary intake, demonstrating the interdependence of ad-driven eating behaviors within the dyad.[137] Another study conducted in-depth interviews with 82 U.S. adolescents and found that while many expressed skepticism toward food ads, they often internalized marketing messages and imagery, particularly surrounding body ideals and social status. Parents emerged as positive role models for nutritional health, while peers often reinforced consumption of marketed foods in social settings.[138] These findings demonstrate that both adolescents and parents are influenced by food advertising, and that shared media exposure and perceptions may interact to shape dietary outcomes.

Dietary Guidelines. The Dietary Guidelines for Americans (DGAs) are developed by the U.S. Department of Agriculture to provide the most updated advice on what to eat and drink to meet nutrient needs, promote health, and prevent disease. However, multiple studies across decades have documented low adherence to the DGAs across the U.S. population, with most individuals failing to meet recommendations for fruits, vegetables, and other key components.[12,15,16] Despite increased public awareness, actual adherence has shown only modest improvements over time, often constrained by socioeconomic barriers and food environment challenges.[85]

The DGAs place emphasis on the consumption of fruits, vegetables, beans, whole grains, and lean protein, which could be categorized as nutrient dense foods (NDF). NDF is defined by the National Institute of Health (NIH) as food that is "...high in nutrients but relatively low in calories. Nutrient-dense foods contain vitamins, minerals, complex carbohydrates, lean protein, and healthy fats."[17] The DGAs also encourage the limitation of foods rich in added sugars, sodium, and saturated fat, which are characteristics of ultra-processed foods (UPF). UPF are defined using the NOVA classification system, developed in 2009 as a means of categorizing foods based on the extent and purpose of their processing.[18] According to this definition, UPF are industrial formulations typically including food substances of rare culinary use, such as hydrogenated or interesterified oils, hydrolyzed proteins, modified starches, and varieties of sugars. They also contain additives designed to increase shelf-life, palatability, and consumer appeal, such as artificial sweeteners, emulsifiers, flavor enhancers, and colorants.[139] Common examples of UPF include packaged snacks, soft drinks, and reconstituted meat products.

Shifting to dietary patterns that include more UPF is a significant public health concern due to strong evidence linking UPF consumption with adverse health outcomes. The growing body of epidemiological research has demonstrated consistent associations between high UPF intake and poor dietary quality,[3] increased energy intake and weight gain,[4] and elevated risk for chronic diseases including obesity,[57] type 2 diabetes,[7] cardiovascular disease,[5] and all-cause mortality.[5,10,140] These findings

suggest that as UPF displace NDF in the diet, they actively contribute to the risk of developing cardiometabolic diseases. Thus, it is important to study how various factors affect UPF and NDF intake and to utilize this understanding in the design and implementation of public health programs.

Why Interventions Fail

Despite widespread public health efforts to promote healthy eating among youth and families, many nutrition interventions in the U.S. have shown limited or short-lived impacts. Systematic and umbrella reviews that evaluated the outcomes of educational and behavioral interventions for adolescents found that while these programs improve nutrition knowledge, few show evidence that they produce long-term dietary changes.[26,29] Similarly, both experimental and review studies found that school-based interventions targeting UPF also show limited effectiveness for long-term improvements in diet quality.[30,31] These modest results could be largely attributed to the fact that most interventions often focus narrowly on individual behavior change without accounting for the broader environmental and systemic contexts in which those behaviors occur.

The Academy of Nutrition and Dietetics has acknowledged this issue, emphasizing that sustained improvements in diet require systems-level approaches, including school, family, and policy environments.[33] Some interventions are shifting to address multiple interacting influences on dietary behavior and found more promising

results. A systematic review of nutrition programs targeting American Indian/Alaska Native youth, for instance, found that only those incorporating cultural adaptations, community-based participatory, and caregiver engagement had significant, albeit slight, impacts on nutrition knowledge and dietary adherence, highlighting the importance of designing interventions from a systems-aware perspective.[27] In one of the systematic reviews previously mentioned, the authors recommended that in theoretically grounded programs, approaches with parental involvement may have the potential to be successful,[26] and more recent programs have begun incorporating media literacy and parent-child communication to reduce the impact of food advertising. A family-based media intervention was shown to improve the ratio of healthy-to-unhealthy food at home and increase youth consumption of fruits and vegetables, demonstrating the power of addressing shared influences between parents and adolescents.[141]

To summarize, U.S.-based nutrition interventions targeting youth and families often fail to produce meaningful or lasting improvements because they treat dietary behavior as an isolated, individual issue. For greater impact, programs must shift toward multifactorial, systems-level designs that consider the full spectrum of factors influencing food choices. Taken together, these findings demonstrate the need for systems-level approaches that account for the complex, interdependent influences on dietary behavior. Addressing UPF intake, particularly among adolescents, requires

moving beyond simple education and toward interventions that engage entire environments.

Multilevel Modeling in Nutrition Research

Public health researchers have increasingly turned to systems thinking as a framework for understanding complex, interrelated factors that influence health behaviors. Systems thinking recognizes that outcomes like dietary intake are not the result of isolated causes but instead emerge from the interactions among multiple factors across individual, environmental, and policy levels. By modeling dietary behavior within a multivariable and multilevel system, researchers can identify which factors exert the strongest influence, both independently and in combination. Statistical methods such as structural equation modeling (SEM) and multilevel linear modeling (MLM) have been used to examine how food availability, parental behaviors, and motivational constructs interact to shape child diet outcomes. Studies have demonstrated the value of multilevel modeling in understanding dietary intake and health outcomes of parents and adolescents. For example, one study on youth obesity using multilevel modeling found that while family factors accounted for the majority of variance in childhood obesity, school and community level influences also contributed to the variance, affirming the relevance of modeling across levels.[142]

Within multilevel statistical methods, multilevel linear regression is a robust analytical approach for simultaneously examining a system of factors and their

association with health behaviors within hierarchical data structures, such as parent-adolescent dyads. Most significantly, this type of regression accounts for similarity between dyad members and allows comparison of interaction relationships between the parent and the adolescent. By accounting for interdependencies and predictors at multiple levels, results from this method allow for a more realistic and impactful understanding of how to design interventions that target the most influential factors. The Family Life, Activity, Sun, Health, and Eating (FLASHE) Study, conducted by the National Cancer Institute in 2014, is a publicly available data source designed to capture health behaviors (i.e., diet, physical activity, and cancer-preventive health behaviors) among U.S. parents-adolescent dyads.[143] Data collected during this study provides a valuable opportunity to modeling for multiple predictors that affect both parents and adolescents. However, studies using this data for multilevel modeling tend to focus on only the adolescents and do not fully explore the dyad aspect of the FLASHE study and data.[117,119,144] There exists an opportunity to leverage multilevel linear regression modeling to comprehensively examine the system of socio-environmental factors that affect dietary outcomes in the context of the parent-adolescent dyad.

Summary

Increase in UPF intake in the U.S. represents a pressing public health concern, as high UPF intake is associated with poor nutrient intake and elevated risks for

cardiometabolic disorders. Despite public health interventions attempting to address this issue, results have been modest, short-term, and less effective in marginalized populations. This may be due to approaches narrowly targeting individual knowledge or behaviors while overlooking the complex, multi-layered systems in which dietary behaviors occur.

An expanding body of literature highlights the diverse socio-environmental factors shaping dietary behavior across the social ecological model, at the individual, interpersonal, community, and policy levels. While many of these factors are independently linked to UPF and NDF intake, the strength and direction of these associations often vary based on context. At the individual level, weight status shows varied associations with dietary outcomes. At the family level, parents and their adolescents may be influencing each other's diets. At the household level, SES, food purchasing, eating away from home, eating in the home, availability of foods in the home, and home food environment all demonstrate some associations with dietary outcomes, but nuances exist when other factors are considered in the associations. At the community level, school food environment and availability show mixed impact in adolescent dietary outcomes. At the policy level, perception and trust towards advertisements is shown to be associated with higher consumption of UPF. While the DGA encourages consumption of NDF and recommend limitations in UPF, there is low adherence across the U.S. population.

To address these gaps, this thesis will apply multilevel linear regression modeling to the FLASHE dataset to examine how a system of individual, household, and environmental factors jointly predict dietary intake in both parents and adolescents. This study aims to examine how multiple socio-environmental factors are associated with UPF and NDF intake among U.S. parents and adolescents, as well as whether these factors are more significantly associated with dietary outcomes than individual factors such as weight status. By modeling dietary intake as shaped by multiple interdependent predictors, this thesis seeks to offer a more nuanced understanding of how socio-environmental factors interdependently affect UPF and DNF intake for parent-adolescent dyads, informing how policies and interventions could more effectively address dietary outcomes.

METHODS

Study Population and Data Source

This secondary data analysis was conducted using publicly accessible data derived from the Family Life, Activity, Sun, Health, and Eating (FLASHE) study. The FLASHE study was a dyadic, cross-sectional study conducted by the National Cancer Institute (NCI) between April and October 2014 examining psychosocial, generational, and environmental determinants of cancer-preventive behaviors within parent-adolescent dyads.[49] The study was conducted with a demographically representative U.S. sample of parents and adolescents recruited from the Ipsos' Consumer Opinion Panel. A parent (mother or father) and one adolescent were sampled from each participating household, and a total of 1945 dyads were enrolled in the study. Eligible adults were at least 18 years of age and lived with the adolescent at least 50% of the time. Eligible adolescents were between the ages of 12-17 and lived in the parent's household at least 50% of the time.

FLASHE employed two web-based, cross-sectional surveys for each participant, one focusing on diet and the other on physical activity. A demographic information model was attached to whichever survey was given first. A dyadic numerical identifier was used to link parent and adolescent data. The current study uses survey data assessing participants' dietary correlates and outcomes, as well as demographic characteristics. Out of the 1945 parent-adolescent dyads enrolled in FLASHE, 1890 dyads provided responses to variables employed in the current study.

Additional details on the FLASHE survey and methodology were previously described.[143]

Study Measures

Items measured in the FLASHE study were modified or drawn from validated and reliable instruments using cognitive testing. Source information and full surveys can be found elsewhere.[143]

Dependent Measures

Ultra-processed food (UPF) and nutrient-dense food (NDF) consumption. The current study analyzes dietary behavioral outcomes using four sets of target measurements: UPF consumption of parents, UPF consumption of adolescents, NDF consumption of parents, and NDF consumption of adolescents. Survey questions were developed using the Dietary Screener Questionnaire in the NHANES 2009-2010[145] and the 2010 National Youth Physical Activity and Nutrition Study.[146] Foods and beverages included in the diet surveys were categorized into UPF or NDF following the Dietary Guidelines for Americans, 2020-2025.[147] The category of NDF consisted of water, whole fruits, vegetables, beans, green salad, unfried potatoes, other non-fried vegetables, whole grain bread, cooked whole grains, and non-sugary cereal. The UPF category consisted of fruit drinks, soda, energy drinks, sports drinks, fried potatoes, tacos, heat-and-serve meals, processed meats, burgers, fried chicken, candy, cake,

desserts, chips, and sugary cereal. The FLASHE diet surveys assessed dietary intake of the participants using questions asking about the frequency of consumption of various foods or beverages in the previous 7 days. For example: "DURING THE PAST 7 DAYS, how many times did you drink any WATER that is not sweetened like tap water, filtered water, bottled water or sparkling water?" Answers were scored from 1-6, with 1 representing "I did not drink water during the past 7 days," 2 representing "1-3 times in the past 7 days," 3 representing "4-6 times in the past 7 days," 4 representing "1 time per day," 5 representing "2 times per day," 6 representing "3 or more times per day." Survey responses were converted into daily frequencies following the procedures of NHANES 2009-2010 frequency conversion[148] and summed within the UPF or NDF groups.

Independent Measures

Weight status. Weight status was denoted using BMI categories. BMI percentile of adolescents was computed from height and weight as proxy-reported by their parents and organized by the FLASHE team into 4 categories: underweight (BMI < 5th percentile), healthy weight (BMI 5th to < 85th percentile), overweight (BMI 85th to < 95th percentile), and obese (BMI ≥ 95th percentile).[149] Parents' weight status was determined by calculating BMI from self-reported height and weight and organized by the FLASHE team into 4 categories: underweight (< 18.5), healthy weight (18.5-24.99), overweight (25-29.99), and obese (≥ 30).[143] These results were

further dichotomized as healthy weight or overweight and obese; responses for being in the underweight category were omitted as their distribution was less than 5%. These two BMI categories were entered in statistical models using dummy coding by representing healthy weight with 0 as the baseline level and using 1 to indicate overweight or obese status.

Food purchasing. Food purchasing was denoted using four items characterizing the type of stores visited by the parent buying household food. The source of this measure in FLASHE is the Food Attitudes and Behaviors Survey.[150] Parents answered the survey question "In the past month, how often did you get food from the following places: a. Convenience/corner store/small grocery store/bodega; b. Supermarket/mid-size grocery store; c. Fruit/vegetable market/Farmer's market/ coop/Community Supported Agriculture (CSA); d. Warehouse club store (such as Sam's Club or Costco) or Discount superstore (such as WalMart)." Answers were scored from 1-5, representing "Never," "Rarely," "Sometimes," "Often," and "Always," respectively. In order to develop the composite score, responses were re-coded to range from 0-4. To scale all responses in the same direction as factors generally associated with higher NDF and lower UPF intake, visits to convenience stores, which typically carry a relatively smaller selection of NDF, were reverse coded so that a smaller score represents more frequent visits, and all scores were summed.

Eating away from home. Parents' and adolescents' eating behavior away from home was assessed using four items adapted from the TREC Idea Study.[151] This instrument measures the frequency of having meals and snacks eaten outside of the home at restaurants or convenience stores in the past 7 days. Parents and adolescents each answered the survey question "During the past 7 days, ON HOW MANY DAYS did you eat at least one meal or snack AWAY FROM HOME at... a. A fast food restaurant like McDonald's, Taco Bell or KFC?; b. A full service pizza restaurant like Pizza Hut, Godfather's or CiCi's Pizza?; c. A convenience store like 7-Eleven or Express Mart?; d. A full service restaurant like Red Lobster, TGIFridays, Chili's or an independent restaurant?" Answers were scored from 0-7, representing "On 0 days" through "On 7 days," respectively. To scale all responses into the same direction as factors generally associated with higher NDF intake and lower UPF intake, all scores were reverse coded so that more frequent visits are represented by smaller scores, and all scores were then summed to form the composite.

Eating in the home. Parents and adolescent eating behavior in the home was assessed using four items. The FLASHE team developed a survey question to measure the type of evening meals eaten in the home (e.g. fast food, pizza, readymade meal) and the frequency with which it is eaten in the past 7 days as answered by the parent or the adolescent. Parents and adolescents each answered the survey question "Please think about the evening meals eaten AT YOUR HOME in the past 7 days. On how

many of the past 7 days was the evening meal… a. Purchased from a fast food restaurant and eaten AT HOME?; b. Delivered to your HOME like pizza or Chinese food?; c. Made from a HEAT AND SERVE or box meal like Spaghetti-O's, a microwave meal or frozen pizza, and eaten AT HOME?; d. Cooked from scratch or a recipe and eaten AT HOME?" Answers were scored from 0-7, representing "On 0 days" through "On 7 days," respectively. For analytic purposes and based on low frequencies of responses for higher number of days, responses were further categorized following methodology by Thomson et al as 0, 1, and ≥ 2 days/week for all items except meals cooked from scratch which was categorized as 0-3, 4-5, and 6-7 days/week.[106] The three categories were then scored from 0-3 respectively. To scale all responses in the same direction as factors generally associated with higher NDF and lower UPF intake, all scores other than those representing meals cooked from scratch were reverse coded so that a smaller score represents more frequent meals brought from outside, and all scores were then summed to form the composite.

Availability of foods in the home. Parents and adolescent home food availability was denoted using four items adapted from the National Youth Physical Activity and Nutrition Study[146] and Project Eat-II Survey.[152] These items collectively measure how often fruits and vegetables, sweets, sugary drinks, and chips are available in the home. Parents and adolescents each answered the survey question "How often are the following foods and drinks available in your home? a. Fruits or

vegetables; b. Sweets like candy, cookies, cake, ice cream, etc.; c. Sugary drinks like regular soda, sports drinks, fruit drinks, sweetened teas and other drinks with added sugar; d. Regular potato chips, corn chips or cheese puffs like Lays, Doritos, Cheetos, etc." Answers were scored from 1-5, representing "Never," "Rarely," "Sometimes," "Often," and "Always," respectively. To develop the composite score, responses were re-coded to range from 0-4. To scale all responses in the same direction as factors generally associated with higher NDF and lower UPF intake, all scores other than those representing fruits and vegetables were reverse coded so that more frequent availability of sweets, sugary drinks, and chips are associated with smaller scores. All scores were then summed to form the composite score.

Parent home food environment and Adolescent school food environment. Home food environment was assessed using four items developed from Neighborhood Environment Walkability Scale for Youth.[153] Parents answered *Yes/No* to the survey question "Think about your neighborhood, which is the local area around your home, within a 10-15 minute walk in any direction. Which of the following do you have in your neighborhood? Please select all that apply. a. Convenience/corner store/small grocery store/bodega; b. Supermarket (or mid-size grocery store); c. Fruit/vegetable market (or Farmer's market/ co-op/Community Supported Agriculture (CSA); d. Fast food restaurant; e. Non-fast food restaurant," with *Yes* scored as 1 and *No* as 2. Similarly, Adolescent school food environment was assessed using the same items and

adolescents answered to the survey question modified to be about the local area around the adolescents' school, with *Yes* scored as 1 and *No* as 2. To develop the composite score, responses were re-coded to score *Yes* as 0 and *No* as 1. To scale all responses in the same direction as factors generally associated with higher NDF and lower UPF intake, visits to convenience stores, fast food restaurants, and non-fast food restaurants were reverse-coded so that the ease of reaching these food stores are represented by a larger score, and all scores were summed.

Adolescent school food availability. Adolescent school food availability was denoted using five items.[143] Adolescents answered the survey question "How often do you go to each of the following that's in walking distance from your school? a. Convenience/corner store/small grocery store/bodega: b. Supermarket/mid-size grocery store; c. Fruit/vegetable market/Farmer's market/ co-op/Community Supported Agriculture (CSA); d. Fast food restaurant; e. Non-fast food restaurant." Answers were scored from 1-5, representing "Never," "Rarely," "Sometimes," "Often," and "Always," respectively. To develop the composite score, responses were re-coded to range from 0-4. Similar to the reverse-coding for Adolescent School Food Environment, visits to convenience stores, fast food restaurants, and non-fast food restaurants were reverse-coded so that the ease of reaching these food stores are represented by a smaller score, and all scores were summed.

Perception and trust of food advertisements. Perception and trust of food advertisements were measured using three items for both the parent and the adolescent.[143] Parents and adolescents answered the survey question "Please think about messages you see or hear on television, magazines, radio, internet or billboards about foods and drinks. Please select how much you disagree or agree with each of the statements listed below. When I see advertisements for foods or drinks… a. I want to try the advertised foods or drinks; b. I think the advertised foods or drinks will taste good; c. I trust the messages advertised." Answers were scored from 1-5, representing "Strongly disagree," "Somewhat disagree," "Neither disagree nor agree," "Somewhat agree," and "Strongly agree," respectively. To develop the composite score, responses were re-coded to range from 0-4. To scale all responses in the same direction as factors generally associated with higher NDF and lower UPF intake, all responses were reverse-coded so that less trust in advertisements is represented by higher scores. Scores were then summed to form the composite.

Household food security. Food security was measured using a validated two-item screener question.[154] Parents rated the statements "We worried whether our food would run out before we got money to buy more," and "The food that we bought just didn't last, and we didn't have money to get more." as never true, sometimes true, or often true for themselves or someone in their household in the past 12 months,

represented by scores from 1-3. To develop the composite score, responses were re-coded to range from 0-2 and then summed.

Covariates

Adjusted models accounted for participants' age, sex, race/ethnicity, household income, and parent highest degree of education. Parents reported their age with response options including ages below 35, ages 35-44, ages 45-59, and ages above 60. Parents' age categories were represented in the models by a set of three dummy-coded variables using ages below 35 as the baseline. Adolescents reported their age from 12 years old to 17 years old, represented in the models by a set of six dummy-coded variables using 12 years old as the baseline. Participants reported their sex as male or female, and responses were dummy-coded with male as the baseline. Participants reported their race/ethnicity from the options of non-Hispanic White alone, non-Hispanic Black alone, Hispanic, or other. Race/ethnicity categories were represented in the models by a set of three dummy-coded variables using non-Hispanic White alone as the baseline. For household income, parents answered for the combined pre-tax income including all members of the family living in their household in the past 12 months. While the survey question gave multiple response options of incremental amounts in USD, in FLASHE data these responses were coded dichotomously, only making the distinction for household annual income of either $0-$99,999 or $100,000 or more. For modeling, these two income categories were dummy-coded, with $0-

$99,999 as the baseline. Parents provided answers for the highest grade or level of education they completed. Response options included less than a high school degree, a high school degree or GED (where GED = General Educational Development), some college but not a college degree, and a 4-year college degree or higher. Responses are represented as categorical variables using dummy-coding, with the having less than a high school degree as the baseline.

Statistical Analysis

All analyses were conducted using Stata (Stata SE-Standard Edition version 18.0, StataCorp LLC., College Station, TX., USA). Descriptive statistics were used to examine demographic variables and BMI. A pairwise correlation matrix was used to examine the bivariate relationship between dietary outcomes and socio-environmental factors using pairwise complete observations. The linearity assumption for the multilevel regression models was visually verified using two-way scatter plots for each pair of independent and dependent variables.[155] Final multilevel linear regression models with random effects for dyads were fitted using restricted maximum likelihood estimation and the residual degrees of freedom method using the mixed command in Stata.[156] Missing responses for the models were addressed using listwise deletion. The rate of missing data was below 20%. Due to the hierarchical structure of data, unconditional dependency between dyad members was verified by computing the intraclass correlation coefficient of the null models for UPF consumption and NDF

consumption.[155] Normality was verified by using a visual assessment of residual plots and histograms of residuals.[155] Multicollinearity was verified by computing the generalized variance inflation factor of each variable, and a factor below 10 was considered acceptable.[157,158]

RESULTS

Sample Characteristics and Descriptive Statistics

A total of 1890 dyads were included in this study, but only 1581 were accounted for in the final model. Figure 1 depicts the sample size at each analytical stage.

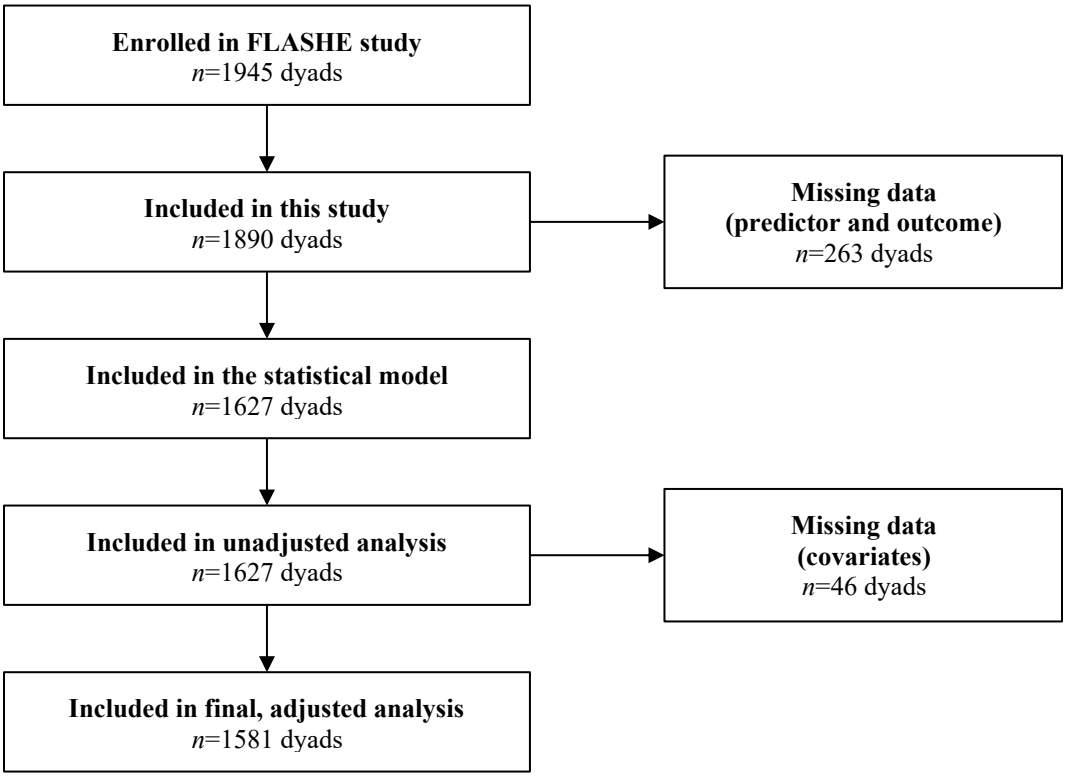

Figure 1. Flow diagram showcasing sample sizes for analysis stages. Listwise deletion was used to handle missing data.

In the sample included in this study, a greater proportion of the parent sub-sample were mothers (73.90%) compared to fathers (26.10%). Over half of the parent

sub-sample were either in the BMI category of overweight (30.74%) or obese (31.47%). Nearly half of the parent sub-sample (46.45%) had a 4-year college education or higher. Overall, two-thirds (69.12%) of parent participants identified as non-Hispanic white, 17.66% were non-Hispanic Black, 7.31% identified as Hispanic, and 5.91% as "other." Most parents (79.35%) reported a household income under $100,000 per year. In the adolescent sub-sample, approximately half (50.24%) of the sample were girls and half (49.76%) were boys. Majority of the adolescent sub-sample (68.25%) were in the healthy weight category for BMI, 15.11% were in the overweight category, and 12.37% in the obese category. Overall, 63.69% of adolescent participants identified as non-Hispanic white, 16.99% identified as non-Hispanic black, 10.08% identified as Hispanic, and 9.24% identified as "other." Table 1 shows additional demographic characteristics for participants.

Table 1. Demographic characteristics of study participants

Variable	*n*	*%*
Parent Sex		
Female	1325	73.90%
Male	468	26.10%
Adolescent Sex		
Female	843	50.24%
Male	835	49.76%
Parent Ethnicity/Race		
Hispanic	130	7.31%
Non-Hispanic Black alone	314	17.66%

Non-Hispanic White alone	1229	69.12%
Other	105	5.91%
Adolescent Ethnicity/Race		
Hispanic	168	10.08%
Non-Hispanic Black	283	16.99%
Non-Hispanic White	1061	63.69%
Other	154	9.24%
Parent BMI Category		
Underweight	25	1.41%
Normal Weight	645	36.38%
Overweight	545	30.74%
Obese	558	31.47%
Adolescent BMI Category		
Underweight	70	4.27%
Normal Weight	1120	68.25%
Overweight	248	15.11%
Obese	203	12.37%
Parent Highest Degree of Education		
Less than a high school degree	2200	1.23%
A high school degree or GED	301	16.84%
Some college but not a college degree	634	35.48%
A 4-year college degree or higher	830	46.45%
Household Income (USD)		
$0-$99,999	1406	79.35%
$100,000 or more	366.00%	20.65%

GED, General Educational Development

Bivariate Associations

Correlations between the continuous independent variables and parent and adolescent dietary outcomes are reported in Table 2. At the bivariate level, parent NDF consumption, parent UPF consumption, adolescent NDF consumption, and adolescent UPF are each significantly correlated, with the strongest correlation between parent and adolescent UPF consumptions (r=0.64, p<0.001). Amongst the 15 continuous socio-environmental predictors, 6 were significantly correlated with parent NDF consumption, with parent availability of food in the home showing the strongest correlation (r=0.22, p<0.001). For adolescent NDF consumption, 7 predictors were significantly correlated, with adolescent availability of food in the home being the strongest (r=0.24, p<0.001). For both parent and adolescent UPF consumption, 10 of the predictors were significantly correlated. The factor with strongest correlation for parent UPF consumption is parent eating away from home (r=-0.45, p<0.001), while for adolescent UPF consumption it is adolescent eating away from home (r=-0.42, p<0.001). In general, significant correlations are also found between most of the independent variables.

Table 2. Pairwise correlation matrix between parent and adolescent dietary outcomes and theoretically relevant continuous socio-environmental predictors

Variable	n	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Parent NDF consumption	1744	5.86	3.00	—																
2. Adolescent NDF consumption	1657	5.23	3.18	0.54***	—															
3. Parent UPF consumption	1744	3.61	3.37	0.23***	0.28***	—														
4. Adolescent UPF consumption	1657	4.88	3.99	0.16***	0.37***	0.64***	—													
5. Food purchasing	1743	8.78	2.15	0.26***	0.20***	0.02	0.03	—												
6. Parent eating away from home	1742	5.90	1.86	0.03	-0.06*	-0.45***	-0.33***	0.04	—											
7. Adolescent eating away from home	1656	5.75	1.95	-0.03	-0.12***	-0.32***	-0.42***	0.01	0.56***	—										
8. Parent eating in the home	1739	5.46	2.04	0.13***	-0.04	-0.42***	-0.32***	0.09***	0.54***	0.41***	—									
9. Adolescent eating in the home	1657	5.15	2.04	0.13***	0.08***	-0.31***	-0.36***	0.06*	0.45***	0.53***	0.67***	—								
10. Parent availability of food in the home	1740	8.12	2.84	0.22***	0.16***	-0.34***	-0.29***	0.07**	0.22***	0.13***	0.25***	0.21***	—							
11. Adolescent availability of food in the home	1657	8.06	2.78	0.20***	0.24***	-0.28***	-0.33***	0.09***	0.20***	0.19***	0.23***	0.28***	0.70***	—						
12. Parent home food environment	1743	1.97	0.92	0.05*	0.06*	-0.02	-0.03	0.05*	0.02	0.07**	0.06*	0.06*	0.08***	0.07**	—					
13. Adolescent school food environment	1656	1.87	0.93	-0.01	0.00	0.00	-0.02	0.02	0.04	0.08***	0.02	0.03	0.04	0.03	0.27***	—				
14. Adolescent school food availability	1654	10.80	1.83	-0.02	0.02	-0.12***	-0.17***	0.01	0.20***	0.34***	0.17***	0.24***	0.04	0.09***	0.16***	0.34***	—			
15. Parent perception of advertisements	1742	5.78	2.66	9.94	0.01	-0.25***	-0.16***	-0.02	0.23***	0.19***	0.25***	0.21***	0.22***	0.20***	0.06*	0.03	0.12***	—		
16. Adolescent perception of advertisements	1657	4.90	2.70	0.03	0.04	-0.13***	-0.17***	0.00	0.14***	0.16***	0.15***	0.15***	0.13***	0.17***	0.04	0.05	0.11***	0.44***	—	
17. Home food security	1740	3.19	1.19	0.08**	0.04	-0.16***	-0.11***	0.07*	0.04	0.04	0.14***	0.13***	0.00	-0.03	0.05*	0.02	0.03	0.07**	0.10***	—

NDF, nutrient-dense foods; UPF, ultra-processed foods.
Coefficients with asterisk are significant (* $p<0.05$, ** $p<0.01$, ** $p<0.001$).

Multilevel Linear Regression Analyses

Results from the standardized multilevel linear regression tests examining the association of socio-environmental factors and NDF consumption for both parent and adolescent are presented in Table 3. Food purchasing (β_p=0.66, SE=0.07, p=0.000; β_a=0.50, SE=0.07, p=0.000), eating in the home (β_p=0.30, SE=0.08, p=0.000; β_a=0.27, SE=0.08, p=0.001), and availability of food in the home (β_p=0.54, SE=0.07, p=0.000; β_a=0.66, SE=0.07, p=0.000) were positively associated with both parent and adolescent NDF consumptions. Eating away from home was negatively associated with both parent and adolescent NDF consumption (β_p=-0.17, SE=0.08, p=0.036; β_a=-0.59, SE=0.08, p=0.000). Additionally, home food security was positively associated with adolescent NDF consumption (β_a=0.15, SE=0.08, p=0.043). Within these significant factors, food purchasing was the strongest predictor for parent NDF consumption (β_p=0.66, SE=0.07, p=0.000), and ability of food in the home was the strongest predictor for adolescent NDF consumption (β_a=0.66, SE=0.07, p=0.000). Having a BMI in the overweight or obese categories was negatively associated with both parent and adolescent NDF consumptions (β_p=-0.39, SE=0.14, p=0.005; β_a=-0.38, SE=0.15, p=0.010). The association of food purchasing and NDF consumption was statistically significantly stronger for the parent ($\Delta\beta$=-0.16, SE=0.08, p=0.041), while the partial association between eating away from home and NDF consumption was significantly stronger for the adolescent ($\Delta\beta$=-0.42, SE=0.10, p=0.000). Additionally, there was a statistically significant difference between parent and

adolescent for the association between school food availability and NDF consumption, but school food availability was not a significant predictor of NDF consumption for either parent or adolescent. The conditional effect of the adolescent given average scores on continuous measures was negative and statistically significant ($\Delta\beta$=-0.74, SE=0.12, p=0.000).

Table 3. Standardized multilevel linear regression analysis of socio-environmental variables and NDF consumption of parent and adolescent

	Parent NDF			Adolescent NDF			Interaction		
	β (SE)	**95% CI**	***p***	**β (SE)**	**95% CI**	***p***	**Δβ (SE)**	**95% CI**	***p***
Food purchasing	0.66 (0.07)	[0.52, 0.80]	0.000	0.50 (0.07)	[0.35, 0.65]	0.000	-0.16 (0.08)	[-0.31, -0.01]	0.041
Eating away from home	-0.17 (0.08)	[-0.33, -0.01]	0.036	-0.59 (0.08)	[-0.75, -0.43]	0.000	-0.42 (0.10)	[-0.62, -0.22]	0.000
Eating in the home	0.30 (0.08)	[0.14, 0.46]	0.000	0.27 (0.08)	[0.11, 0.43]	0.001	-0.03 (0.10)	[-0.23, 0.17]	0.744
Availability of food in the home	0.54 (0.07)	[0.40, 0.68]	0.000	0.66 (0.07)	[0.52, 0.81]	0.000	0.12 (0.09)	[-0.05, 0.30]	0.160
Home food environment	0.09 (0.08)	[-0.05, 0.24]	0.202	0.14 (0.08)	[-0.01, 0.29]	0.062	0.05 (0.08)	[-0.11, 0.20]	0.558
School food environment	-0.06 (0.08)	[-0.22, 0.09]	0.415	-0.07 (0.08)	[-0.23, 0.09]	0.377	-0.00 (0.08)	[-0.17, 0.16]	0.936
School food availability	-0.13 (0.08)	[-0.28, 0.03]	0.104	0.12 (0.08)	[-0.05, 0.28]	0.145	0.25 (0.09)	[-0.08, 0.40]	0.004
Advertisements	-0.05 (0.07)	[-0.19, 0.09]	0.5	-0.02 (0.07)	[-0.15, 0.12]	0.815	0.03 (0.09)	[-0.15, 0.21]	0.723
Household food security	0.12 (0.07)	[-0.03, 0.26]	0.117	0.15 (0.08)	[0.00, 0.30]	0.043	0.04 (0.08)	[-0.12, 0.19]	0.633
Weight status									
Overweight and obese	-0.39 (0.14)	[-0.65, -0.12]	0.005	-0.38 (0.15)	[-0.67, -0.09]	0.010	0.01 (0.19)	[-0.37, 0.38]	0.977

NDF, nutrient-dense food

Conditional effect of the adolescent: Δβ=-0.74, SE=0.12, 95% CI=[-0.97, -0.50], p=0.000. The baseline for Weight status was healthy weight.

After adjusting for parent age, adolescent age, sex, race/ethnicity, parent highest level of education, and household income, the model for parent and adolescent NDF consumption yielded mostly similar results with the exception that in the adjusted model, home food security was not significantly associated with adolescent NDF consumption (β_a=0.12, SE=0.08, p=0.129), and the conditional effect of the adolescent was not statistically significant ($\Delta\beta$=-0.15, SE=0.74, p=0.112). Results of the adjusted model are presented in Table 4.

Table 4. Adjusted standardized multilevel linear regression analysis of socio-environmental variables and NDF consumption of parent and adolescent

	Parent NDF			Adolescent NDF			Interaction		
	β (SE)	95% CI	*p*	β (SE)	95% CI	*p*	Δβ (SE)	95% CI	*p*
Food purchasing	0.65 (0.08)	[0.50, 0.80]	0.000	0.48 (0.08)	[0.33, 0.63]	0.000	-0.17 (0.08)	[-0.31, -0.01]	0.030
Eating away from home	-0.20 (0.08)	[-0.36, -0.04]	0.017	-0.56 (0.08)	[-0.72, -0.40]	0.000	-0.42 (0.10)	[-0.62, -0.22]	0.001
Eating in the home	0.31 (0.09)	[0.14, 0.47]	0.000	0.27 (0.08)	[0.11, 0.44]	0.001	-0.03 (0.10)	[-0.23, 0.17]	0.731
Availability of food in the home	0.55 (0.07)	[0.41, 0.69]	0.000	0.66 (0.08)	[0.53, 0.82]	0.000	0.12 (0.09)	[-0.05, 0.30]	0.147
Home food environment	0.09 (0.08)	[-0.06, 0.24]	0.253	0.12 (0.08)	[-0.03, 0.28]	0.117	0.05 (0.08)	[-0.11, 0.20]	0.672
School food environment	-0.07 (0.08)	[-0.23, 0.08]	0.354	-0.06 (0.08)	[-0.23, 0.10]	0.441	-0.00 (0.08)	[-0.17, 0.16]	0.889
School food availability	-0.14 (0.08)	[-0.30, 0.02]	0.083	0.09 (0.08)	[-0.08, 0.26]	0.284	0.25 (0.09)	[-0.08, 0.40]	0.008
Advertisements	-0.05 (0.07)	[-0.20, 0.09]	0.471	-0.04 (0.07)	[-0.18, 0.10]	0.565	0.03 (0.09)	[-0.15, 0.21]	0.898
Household food security	0.08 (0.08)	[-0.07, 0.24]	0.284	0.12 (0.08)	[-0.04, 0.28]	0.129	0.04 (0.08)	[-0.12, 0.19]	0.65
Weight status									
Overweight and obese	-0.39 (0.14)	[-0.67, -0.11]	0.006	-0.34 (0.15)	[-0.64, -0.05]	0.023	0.05 (0.20)	[-0.34, 0.43]	0.807

Table 4 (Continued)

	Parent NDF			Adolescent NDF			Interaction		
	β (SE)	**95% CI**	***p***	**β (SE)**	**95% CI**	***p***	**Δβ (SE)**	**95% CI**	***p***
Parent age									
Age 35-44	-0.28 (0.22)	[-0.71, 0.14]	0.187	-0.28 (0.22)	[-0.71, 0.14]	0.187	—	—	—
Age 45-59	-0.18 (0.22)	[-0.62, 0.26]	0.416	-0.18 (0.22)	[-0.62, 0.26]	0.416	—	—	—
Age 60+	-0.21 (0.43)	[-1.05, 0.63]	0.621	-0.21 (0.43)	[-1.05, 0.63]	0.621	—	—	—
Adolescent age									
13 years old	-0.04 (0.22)	[-0.49, 0.38]	0.811	-0.04 (0.22)	[-0.49, 0.38]	0.811	—	—	—
14 years old	-0.03 (0.23)	[-0.49, 0.42]	0.893	-0.03 (0.23)	[-0.49, 0.42]	0.893	—	—	—
15 years old	0.02 (0.23)	[-0.44, 0.47]	0.949	0.02 (0.23)	[-0.44, 0.47]	0.949	—	—	—
16 years old	-0.07 (0.23)	[-0.52, 0.37]	0.746	-0.07 (0.23)	[-0.52, 0.37]	0.746	—	—	—
17 years old	-0.22 (0.25)	[-0.72, 0.28]	0.385	-0.22 (0.25)	[-0.72, 0.28]	0.385	—	—	—
Sex									
Female	0.23 (0.16)	[-0.07, 0.54]	0.136	0.23 (0.16)	[-0.07, 0.54]	0.056	0.02 (0.20)	[-0.37, 0.42]	0.907

Table 4 (Continued)

	Parent NDF			Adolescent NDF			Interaction		
	β (SE)	**95% CI**	***p***	**β (SE)**	**95% CI**	***p***	**Δβ (SE)**	**95% CI**	***p***
Ethnicity/race									
Non-Hispanic Black alone	-0.04 (0.20)	[-0.44, 0.36]	0.856	-0.04 (0.20)	[-0.44, 0.36]	0.356	-0.23 (0.31)	[-0.84, 0.38]	0.455
Hispanic	-0.35 (0.28)	[-0.91, 0.20]	0.213	-0.35 (0.28)	[-0.91, 0.20]	0.160	0.01 (0.43)	[-0.85, 0.87]	0.983
Other	-0.54 (0.30)	[-1.13, 0.05]	0.074	-0.54 (0.30)	[-1.13, 0.05]	0.357	0.24 (0.40)	[-0.54, 1.02]	0.544
Parent highest level of education									
High school degree or GED	-0.24 (0.58)	[-1.37, 0.90]	0.682	-0.24 (0.58)	[-1.37, 0.90]	0.682	—	—	—
Some college but not a college degree	-0.16 (0.57)	[-1.28, 0.95]	0.774	-0.16 (0.57)	[-1.28, 0.95]	0.774	—	—	—
4-year college degree of higher	0.19 (0.57)	[-0.93, 1.30]	0.744	0.19 (0.57)	[-0.93, 1.30]	0.744	—	—	—
Household income									
$100,000 or more	0.11 (0.17)	[-0.23, 0.44]	0.535	0.11 (0.17)	[-0.23, 0.44]	0.535	—	—	—

NDF, nutrient-dense food

Conditional effect of the adolescent: Δβ=-0.15, SE=0.74, 95% CI=[-1.60, 1.31], *p*=0.112. The baseline for Weight status was healthy weight. The baseline for Parent age is below 35. The baseline for Adolescent age is 12 years old. The baseline for Sex is male. The baseline for Ethnicity/race is non-Hispanic White alone. The baseline for Parent highest level of education was less than a high school degree. The baseline for Household income was $0-$99,999.

Table 5 summarizes the partial associations between socio-environmental factors and UPF consumption of the parent and the adolescent as modeled using standardized multilevel linear regression. Food purchasing was positively associated with both parent and adolescent UPF consumption (β_p=0.20, SE=0.08, *p*=0.009; β_a=0.22, SE=0.08, *p*=0.005). Eating away from home (β_p=0.-85, SE=0.08, *p*=0.000; β_a=-1.0, SE=0.08, *p*=0.000), eating in the home (β_p=-0.53, SE=0.08, *p*=0.000; β_a=-0.50, SE=0.08, *p*=0.000), availability of food in the home (β_p=-0.67, SE=0.07, *p*=0.000; β_a=-0.90, SE=0.08, *p*=0.000), perception of advertisements (β_p=-0.33, SE=0.07, *p*=0.000; β_a=-0.23, SE=0.07, *p*=0.001), and household food security (β_p=-0.39, SE=0.08, *p*=0.000; β_a=-0.29, SE=0.08, *p*=0.000) were negatively associated with UPF consumption for both parents and adolescents. Among these significant factors, eating away from home was the strongest predictor for parent UPF consumption (β_p=0.-85, SE=0.08, *p*=0.000) as well as for adolescent UPF consumption (β_a=-1.0, SE=0.08, *p*=0.000). The partial association of availability of food in the home and UPF consumption was statistically significantly stronger for the adolescent ($\Delta\beta$=-0.23, SE=0.08, *p*=0.005). No additional interactions emerged as significant. The conditional effect of adolescents given average scores on continuous measures was positive and statistically significant ($\Delta\beta$=1.00, SE=0.12, *p*=000).

Table 5. Standardized multilevel linear regression analysis of socio-environmental variables and UPF consumption of parent and adolescent

	Parent UPF			Adolescent UPF			Interaction		
	β (SE)	**95% CI**	***p***	**β (SE)**	**95% CI**	***p***	**Δβ (SE)**	**95% CI**	***p***
Food purchasing	0.20 (0.08)	[0.05, 0.36]	0.009	0.22 (0.08)	[0.07, 0.38]	0.005	0.02 (0.07)	[-0.13, 0.16]	0.800
Eating away from home	-0.85 (0.08)	[-1.01, -0.70]	0.000	-1.00 (0.08)	[-1.15, -0.83]	0.000	-0.14 (0.10)	[-0.33, 0.06]	0.170
Eating in the home	-0.53 (0.08)	[-0.69, -0.36]	0.000	-0.50 (0.08)	[-0.67, -0.34]	0.000	0.02 (0.10)	[-0.17, 0.22]	0.819
Availability of food in the home	-0.67 (0.07)	[-0.81, -0.53]	0.000	-0.90 (0.08)	[-1.05, -0.75]	0.000	-0.23 (0.08)	[-0.39, -0.07]	0.005
Home food environment	0.05 (0.08)	[-0.11, 0.21]	0.535	0.12 (0.08)	[-0.04, -0.28]	0.144	0.07 (0.08)	[-0.08, 0.22]	0.361
School food environment	0.11 (0.08)	[-0.06, 0.27]	0.201	0.04 (0.09)	[-0.13, 0.20]	0.680	-0.07 (0.08)	[-0.23, 0.08]	0.359
School food availability	-0.12 (0.08)	[-0.29, 0.04]	0.149	-0.07 (0.09)	[-0.25, 0.10]	0.398	0.05 (0.08)	[-0.11, 0.21]	0.565
Advertisements	-0.33 (0.07)	[-0.48, -0.19]	0.000	-0.23 (0.07)	[-0.36, 0.09]	0.001	0.11 (0.09)	[-0.06, 0.28]	0.218
Household food security	-0.39 (0.08)	[-0.55, -0.24]	0.000	-0.29 (0.08)	[-0.45, -0.14]	0.000	0.10 (0.08)	[-0.05, 0.25]	0.183
Weight status									
Overweight and obese	0.02 (0.13)	[-0.25, 0.29]	0.870	0.07 (0.15)	[-0.21, 0.36]	0.632	0.05 (0.19)	[-0.32, 0.42]	0.797

UPF, ultra-processed food

Conditional effect of the adolescent: β=1.00, SE=0.12, 95% CI=[0.77, 1.23], p=0.000. The baseline for Weight status was healthy weight.

After adjusting for parent age, adolescent age, sex, race/ethnicity, parent highest level of education, and household income, the model for parent and adolescent UDF consumption yielded similar results. Results of the adjusted model are presented in Table 6.

Table 6. Adjusted standardized multilevel linear regression analysis of socio-environmental variables and UPF consumption of parent and adolescent

	Parent UPF			Adolescent UPF			Interaction		
	β (SE)	**95% CI**	***p***	**β (SE)**	**95% CI**	***p***	**Δβ (SE)**	**95% CI**	***p***
Food purchasing	0.22 (0.08)	[0.06, 0.38]	0.007	0.23 (0.08)	[0.07, 0.40]	0.004	0.02 (0.08)	[-0.13, 0.17]	0.822
Eating away from home	-0.87 (0.08)	[-1.03, -0.70]	0.000	-0.99 (0.08)	[-1.15, -0.83]	0.000	-0.12 (0.10)	[-0.32, 0.08]	0.237
Eating in the home	-0.51 (0.09)	[-0.67, -0.34]	0.000	-0.47 (0.09)	[-0.64, -0.30]	0.000	0.04 (0.10)	[-0.16, 0.24]	0.717
Availability of food in the home	-0.68 (0.07)	[-0.83, -0.53]	0.000	-0.92 (0.08)	[-1.07, -0.77]	0.000	-0.24 (0.08)	[-0.40, -0.08]	0.004
Home food environment	0.05 (0.08)	[-0.11, 0.21]	0.544	0.13 (0.08)	[-0.03, -0.30]	0.108	0.08 (0.08)	[-0.07, 0.24]	0.277
School food environment	0.11 (0.08)	[-0.06, 0.28]	0.212	0.04 (0.09)	[-0.13, 0.21]	0.649	-0.07 (0.08)	[-0.23, 0.09]	0.400
School food availability	-0.13 (0.09)	[-0.30, 0.04]	0.141	-0.09 (0.09)	[-0.27, 0.09]	0.312	0.04 (0.08)	[-0.13, 0.20]	0.661
Advertisements	-0.34 (0.07)	[-0.49, -0.20]	0.000	-0.18 (0.07)	[-0.32, 0.04]	0.012	0.16 (0.09)	[-0.01, 0.34]	0.071
Household food security	-0.38 (0.08)	[-0.54, -0.21]	0.000	-0.24 (0.09)	[-0.40, -0.07]	0.005	0.14 (0.08)	[-0.01, 0.29]	0.074
Weight status									
Overweight and obese	0.03 (0.14)	[-0.24, 0.30]	0.827	0.02 (0.15)	[-0.27, 0.32]	0.87	-0.01 (0.19)	[-0.38, 0.37]	0.975

Table 6 (Continued)

	Parent UPF			Adolescent UPF			Interaction		
	β (SE)	**95% CI**	***p***	**β (SE)**	**95% CI**	***p***	**Δβ (SE)**	**95% CI**	***p***
Parent age									
Age 35-44	-0.37 (0.24)	[-0.84, 0.10]	0.119	-0.37 (0.24)	[-0.84, 0.10]	0.119	—	—	—
Age 45-59	-0.57 (0.25)	[-1.06, 0.09]	0.021	-0.57 (0.25)	[-1.06, 0.09]	0.021	—	—	—
Age 60+	-0.73 (0.47)	[-1.66, 0.19]	0.121	-0.73 (0.47)	[-1.66, 0.19]	0.121	—	—	—
Adolescent age									
13 years old	-0.20 (0.25)	[-0.70, 0.28]	0.415	-0.20 (0.25)	[-0.70, 0.28]	0.415	—	—	—
14 years old	-0.02 (0.26)	[-0.52, 0.49]	0.944	-0.02 (0.26)	[-0.52, 0.49]	0.944	—	—	—
15 years old	-0.27 (0.26)	[-0.77, 0.24]	0.305	-0.27 (0.26)	[-0.77, 0.24]	0.305	—	—	—
16 years old	-0.12 (0.25)	[-0.61, 0.38]	0.638	-0.12 (0.25)	[-0.61, 0.38]	0.638	—	—	—
17 years old	-0.38 (0.28)	[-0.94, 0.17]	0.175	-0.38 (0.28)	[-0.94, 0.17]	0.175	—	—	—
Sex									
Female	-0.25 (0.15)	[-0.56, 0.05]	0.101	-0.30 (0.13)	[-0.56, -0.04]	0.024	-0.05 (0.20)	[-0.44, 0.35]	0.818

Table 6 (Continued)

	Parent UPF			Adolescent UPF			Interaction		
	β (SE)	**95% CI**	***p***	**β (SE)**	**95% CI**	***p***	**Δβ (SE)**	**95% CI**	***p***
Ethnicity/race									
Non-Hispanic Black alone	-0.14 (0.21)	[-0.56, 0.28]	0.523	0.43 (0.30)	[-0.16, 1.03]	0.155	0.57 (0.31)	[-0.04, 1.18]	0.068
Hispanic	-0.23 (0.29)	[-0.81, 0.34]	0.431	-0.12 (0.25)	[-0.62, 0.38]	0.644	0.11 (0.47)	[-0.80, 1.02]	0.807
Other	-0.11 (0.31)	[-0.71, 0.49]	0.714	-0.15 (0.33)	[-0.79, 0.50]	0.659	-0.03 (0.40)	[-0.81, 0.75]	0.933
Parent highest level of education									
High school degree or GED	-0.60 (0.64)	[-1.86, 0.65]	0.346	-0.60 (0.64)	[-1.86, 0.65]	0.346	—	—	—
Some college but not a college degree	-1.06 (0.63)	[-2.30, 0.17]	0.092	-1.06 (0.63)	[-2.30, 0.17]	0.092	—	—	—
4-year college degree of higher	-1.03 (0.63)	[-2.27, 0.20]	0.102	-1.03 (0.63)	[-2.27, 0.20]	0.102	—	—	—
Household income									
$100,000 or more	-0.02 (0.19)	[-0.39, 0.35]	0.909	-0.02 (0.19)	[-0.39, 0.35]	0.909	—	—	—

UPF, ultra-processed food

Conditional effect of the adolescent: Δβ=0.96, SE=0.30, 95% CI=[0.38, 1.55], *p*=0.001. The baseline for Weight status was healthy weight. The baseline for Parent age is below 35. The baseline for Adolescent age is 12 years old. The baseline for Sex is male. The baseline for Ethnicity/race is non-Hispanic White alone. The baseline for Parent highest level of education was less than a high school degree. The baseline for Household income was $0-$99,999.

DISCUSSION

The current study examined associations between socio-environmental factors and the intake of NDF and UPF when modeled interdependently using multilevel linear regression among a nationally representative sample of U.S. parents and adolescents. In sum, factors at the household level are generally most significantly associated with diet outcomes compared to neighborhood factors for both parents and adolescents. Having a BMI in the overweight or obese categories was associated with lower consumptions of NDF for both parent and adolescent, but there were no significant associations with UPF intake. This study contributes to the literature regarding dietary intake and socio-environmental factors.

In this study, the socio-environmental factors that emerged with significant associations with both NDF and UPF consumptions were generally those within the household context, such as the type of stores visited by the parent to purchase food, the type of evening meals eaten in the home, and availability of foods in the home. In contrast, factors regarding the broad neighborhood, such as the type of food outlets near the home and the school, were not associated with dietary outcomes. This finding contrasts with existing research that has linked neighborhood food environments to diet quality, particularly among adolescents.[125,128] However, other studies have raised questions about the strength and consistency of these associations, providing evidence that household-level factors may be more strongly associated with dietary consumption of adults and adolescents than neighborhood exposure alone.[120,127,131]

This includes another recent study analyzing FLASHE data to examine the home and neighborhood food environment as predictors of adolescent diet, which found that the home food environment displays a greater number of associations with adolescent diet than the neighborhood food environment.[119] The finding from the current study supports the emerging evidence that the household is the most immediate and impactful food environment for parents and their adolescents. This suggests that interventions targeting dietary outcomes for both parents and adolescents may be more effective when prioritizing the household context.

Within these socio-environmental factors that demonstrated a significant influence particularly at the household-level, the type of stores visited by the parent to purchase food emerged as the only factor that is positively associated with both NDF and UPF intake. This suggests that dietary intake may be more closely linked to what parents choose to purchase rather than the inherent characteristics of store types. In other words, visiting stores that carry a greater selection of NDF, such as supermarkets and warehouse stores, may not translate to the consumption of those foods if shopping patterns prioritize the selection of UPF. Although prior research has found that shopping trips to conventional supermarkets and discount stores were linked to higher diet quality as measured by HEI scores compared to trips to convenience and corner stores,[95,96] this association may be less straightforward when other socio-environmental factors are simultaneously considered. While supermarkets and warehouse stores generally carry more NDF options compared to convenience stores,

they also carry a large selection of UPF. Multiple studies conducted in the U.S. have shown that addition of supermarkets in a neighborhood is not associated with improved diet quality of its residents.[122–124] Considering in conjunction with the lack of associations between the broad neighborhood factors and dietary intake, these findings collectively suggest that increasing the availability of stores with a large NDF inventory is insufficient to address dietary outcomes without active attention to purchasing behavior. Interventions should focus on building shopping habits that encourage choosing NDF over UPF, regardless of what types of stores to shop from. Future research should explore how parental food purchasing decisions are shaped, whether through family preferences, cost considerations, or marketing influences, and how interventions could target these influences to more directly impact food purchasing and thus dietary intake of both parents and adolescents.

Even when accounting for a system of socio-environmental factors, having a BMI in the overweight or obese categories remained significantly associated with lower NDF consumption for parents and adolescents, but it was not associated with UPF consumption. These findings partially contrast with a large body of previous research linking higher BMI to both higher UPF consumption and lower NDF intake,[4,53–57] but one longitudinal study and one systematic review have also documented weak or inconsistent associations between BMI or obesity and dietary components.[58,59] By isolating NDF as the dietary component that is strongly associated with weight status as opposed to UPF, this study adds to the evidence that suggests

reduced diet quality in individuals with higher BMI may be driven more by insufficient intake of NDF than by excessive intake UPF. Rather than focusing exclusively on restricting UPF, interventions that place greater emphasis on encouraging acceptance and intake of NDF may be more effective in improving diet quality among those with obesity. This perspective aligns with intervention frameworks that are non-restrictive, which aim to improve nutritional adequacy without exacerbating stigma around foods or risks of disordered eating.[66,159,160] Future studies should further explore mechanisms through which individuals with higher BMI may consume fewer NDF, whether due to cost barriers, stigma-related avoidance of shopping and cooking, or differences in beliefs and attitudes, and implement intervention strategies that specifically address these barriers.

Interestingly, the conditional effect of the adolescent indicates that for a parent-adolescent dyad with average scores across all continuous independent variables, the adolescent's consumption of UPF is still significantly greater than that of the parent, even after adjusting for covariates. This finding is consistent with previous analyses of U.S. national dietary surveillance data, which showed that adolescents aged 12-19 years receive about 68% of energy intake from UPF,[19] while for adults older than 19 years it is about 57%.[14] Importantly, this difference in intake of UPF in adolescents persistent in the current study even when controlling for shared socio-environmental contexts with the parent, suggesting that factors beyond this context may be driving adolescent UPF intake. One possible mechanism is influences

from peers and siblings, which are shown in a systematic review to increase adolescent UPF consumption.[161] Adolescent autonomy may also influence adolescent food choice and intake, and research has shown that adolescents exert higher autonomy over selection of snacks,[162] which are typically UPF. These findings suggest that adolescent-specific factors compound the effects of shared dyadic socio-environmental factors on UPF intake, supporting the need for future research to identify these factors to develop adolescent-specific strategies in dietary interventions.

Limitations of this study should be noted. Although standardized multilevel linear regressions were computed, because both continuous and categorical variables are present in the model, the size of the coefficients are not directly comparable across variable types. Because of this, it is unable to determine from the results about which socio-environmental factor among all the independent variables is most strongly associated with diet outcome measures. Within the covariates adjusted in the main analysis, household income and parent highest degree of education were both included. However, responses for household income were dichotomized by the FLASHE team at a high cutoff, limiting the information available to be incorporated into the analyses. Furthermore, research by Ogden and colleagues[163,164] using data representative of the U.S. has demonstrated that parent highest degree of education shows a more consistent and reliable association with childhood obesity than household income, supporting the use of parental education as the primary proxy for socioeconomic status. Future research using FLASHE data should consider using

parent highest degree of education rather than household income as the proxy for socioeconomic status. In terms of study design, all measures were self-reported by the participants or proxy-reported by the parent through online surveys, thus the responses may be at risk for recall bias and social desirability bias. As this is a cross-sectional study, casual relationships cannot be established. Finally, the data used in this study was collected in 2014 and is relatively dated. However, this data set remains valuable for research due to its large sample size and comprehensive inclusion of factors that are possibly related to diet outcomes.

Despite these limitations, this study is the first to our knowledge to assess the association between diet outcomes and a system of socio-environmental factors by using multilevel linear regression. This method not only allows modeling of multiple variables simultaneously, but also accounts for correlation between the parent-adolescent dyad and allows for comparison of interaction relationships between dyad members. This study also analyzed data using a nationally representative sample of U.S. parents and adolescents, which makes study findings more generalizable.

CONCLUSION

This study examined how various socio-environmental factors are associated with NDF and UPF consumptions of U.S. parents and adolescents when modeled as one interdependent system. This study found that factors at the household level were more strongly associated with parent and adolescent diet outcomes than neighborhood and school factors. The types of food stores visited by parents for food purchasing were associated with both NDF and UPF intake for both parents and adolescents, suggesting that purchasing decisions impact dietary outcomes more than store and neighborhood characteristics. Weight status was associated with lower NDF intake but not with UPF intake, indicating that nutritional interventions for individuals with higher BMI may benefit from emphasizing consumption of NDF than restriction of UPF. Adolescent consumption significantly more UPF than their parent, even when adjusting for shared socio-environmental contexts, suggesting that adolescent-specific factors for UPF exist beyond this context. These findings support the need for interventions that leverage the home environment to improve NDF intake and reduce UPF intake. Future research should further examine the unique mechanisms that influence adolescent UPF intake.

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