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Processed food consumption is associated with diet quality, but not weight status, in a sample of low-income and ethnically diverse elementary school children

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Abstract

Excess consumption of highly processed foods may be associated with lower diet quality and obesity prevalence, but few studies have examined these relationships in children from low-income households. Therefore, the objective of this study was to evaluate the relationship between food consumption by processing category, diet quality as measured by the Healthy Eating Index-2015 (HEI-2015) and body mass index (BMI) in a sample of low-income children. Data from a study assessing the impact of Summer Food Service participation on diet quality and weight status (N = 131) was used to conduct a cross-sectional analysis of children aged six to twelve years from low-income communities in the Northeastern U.S. Total HEI-2015 score and percentage of calories consumed by processing level were computed per day from three 24-h diet recalls. Multivariable linear regression was used to assess the relationship between percentage of calories from foods by processing category (unprocessed and minimally, basic, moderately and highly processed), HEI-2015 and BMI-z score. The final sample was 58% male and 33.8% obese. On average, children consumed 39.8 ± 17.2% of calories from highly processed foods. A 10% increase in

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R.B.-S. and E.W.E. designed research; R.B.-S., CB and E.W.E. conducted research; R.B.-S., E.W.E and K.C. analyzed data; R.B.-S. wrote the paper. All authors have read and approved the final manuscript.

Declaration of competing interest
None.

Appendix A. Supplementary data
Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2020.104696.

Ethics statement
This analysis used baseline data from an observational study examining the role of the Summer Food Service Program on excess summer weight gain in children aged 6–12 years. The study protocol was approved by the Institutional Review Board at Tufts University.

calories consumed from highly processed foods was associated with a 2.0 point decrease in total HEI-2015 score [95% CI (−2.7, −1.2)], and a 10% increase in calories from minimally processed foods was associated with a 3.0 increase in HEI-2015 score [95% CI (2.1, 3.8)]. Relationships between processing level and BMI-z score were not significant. Among this sample of low-income children, greater intake of highly processed foods was associated with lower dietary quality, but not weight status. Future research should explore prospective associations between food consumption by processing category and weight status in children.

Keywords

Processed food; Ultra-processed; Children; Diet quality; Weight status; Low-income

1. Introduction

Despite national efforts to address childhood obesity, recent estimates suggest that rates continue to rise among youth from low-income and racial/ethnic minority backgrounds (Hales, Carroll, Fryar, & Ogden, 2017, p. 288). Children from low-income families are nearly twice as likely to have obesity as their peers from higher income backgrounds (Ogden et al., 2018). A multitude of individual, family and social factors interact to contribute to this health disparity. These factors include poor diet, which often results from limited access to nutrient-dense foods and an abundance of low-cost, energy-dense, processed foods (Ambrosini, 2014; Poti, Slining, & Popkin, 2014). Accordingly, highly processed food consumption has recently been suggested as a potential contributor to the obesity epidemic, particularly among low-income children (Monteiro, 2009; Monteiro, Levy, Claro, de Castro, & Cannon, 2011; Moubarac et al., 2013).

According to the United States Department of Agriculture (USDA), food processing refers to any procedure that alters food from its natural state ("Chapter 9—Federal Food, Drug, and Cosmetic Act," 2016). Thus, any food aside from raw, agricultural commodities is considered processed. Because of the considerable heterogeneity across processed foods, researchers have developed classification systems to distinguish foods according to the category of processing, ranging from minimally to highly processed (Eicher-Miller, Fulgoni, & Keast, 2012; Monteiro, Levy, Claro, Ribeiro de Castro, & Cannon, 2010; Poti, Mendez, Ng, & Popkin, 2015). One such system, Nova, has been used globally to classify foods and beverages according to the degree of industrial processing (Monteiro et al., 2010). The Nova system was adapted by researchers at the University of North Carolina at Chapel Hill (UNC) to capture the complexity of the American food supply, classifying foods and beverages into four, mutually exclusive categories (Table 1) (Poti et al., 2015). The adapted system was found to have the highest inter-rater reliability among three processing classification systems used in the U.S (Bleiweiss-Sande et al., 2020).

Despite sophisticated classification systems, the effects of food processing on dietary quality remain controversial (Gibney, Forde, Mullally, & Gibney, 2017). Processing can contribute important properties to foods, including enhanced safety, shelf life, and nutritional profiles in the case of fortified products (Dwyer, Fulgoni, Clemens, Schmidt, & Freedman, 2012;

Weaver et al., 2014). However, it is not necessarily a good indicator of nutrient content. Two studies have reported wide variation in nutrient profiles of foods within processing level, suggesting that food choices guided solely on the principle of reducing highly processed food intake could result in less nutrient-dense diets (Eicher-Miller et al., 2012; Poti et al., 2015). In contrast, findings from other studies demonstrate that highly processed foods are higher in saturated fat, added sugar and salt compared to less processed foods (Albuquerque, Santos, Silva, Oliveira, & Costa, 2018; Louzada et al., 2017; Martinez Steele et al., 2016; Poti et al., 2015). There is less research examining the relationship between processed food consumption and overall dietary quality, particularly in children. In a study by Adams et al. of adults in the United Kingdom, the authors found that diets highest in minimally processed foods had the most healthful nutritional profile, while those with the highest levels of highly processed foods had the least healthful dietary profiles (Adams & White, 2015). Comparable results have been published based on evidence from Brazil (Louzada et al., 2017), Canada (Moubarac et al., 2013), and the U.S (Martinez Steele, Popkin, Swinburn, & Monteiro, 2017).

Similarly, there is limited and conflicting evidence on the association between processed food consumption and body weight. The same study by Adams et al. found an inverse association between overall intake of “processed culinary ingredients” (such as sugars and oils) and body weight, but no association specifically with intake of highly processed foods (Adams & White, 2015). In contrast, two cross-sectional analyses of national data from the U.S. and Brazil found that higher intake of “ultra-processed” foods was associated with greater odds of having overweight or obesity (Juul, Martinez-Steele, Parekh, Monteiro, & Chang, 2018; Louzada et al., 2015). A recent inpatient randomized controlled trial of highly processed food intake and weight gain was conducted among overweight adults in the U.S. (Hall et al., 2019). During a two-week period of ad libitum highly processed food intake, participants consumed significantly more calories and gained significantly more weight compared to a two-week period of minimally processed food intake (Hall et al., 2019). However, results of this study are limited to overweight adults and may not be generalizable to children.

There have been two systematic reviews on the topic of highly processed food intake and obesity that included studies in children. The first was a narrative review of articles assessing the relationship between ultra-processed food intake and obesity (Poti, Braga, & Qin, 2017). Of the ten studies identified, three were done in pediatric populations, all among Brazilian cohorts (Rauber, Campagnolo, Hoffman, & Vitolo, 2015; Rinaldi et al., 2016; Tavares, Fonseca, Garcia Rosa, & Yokoo, 2012). Two of these studies examined metabolic syndrome, with one cross-sectional study finding a positive association between highly processed food intake and metabolic syndrome in adolescents (Tavares et al., 2012), and a second cross-sectional study finding no association among school-aged children (Rinaldi et al., 2016). The second systematic review surveyed available literature on the relationship between highly processed food consumption and body fat during childhood and adolescence (Costa, Del-Ponte, Assuncao, & Santos, 2017). Although most included studies showed a positive association, comparability between results was limited by lack of a standardized system for classifying processed foods, and most studies examined single foods (such as sugar-sweetened beverages) or group of foods (such as fast-foods) rather than using a measure of total diet (Costa et al., 2017).

Given the continued rise in social inequalities in obesity among at-risk youth, additional research is warranted to understand these in-consistent findings in the context of children's diets. To our knowledge, no study has examined the association between food intake by processing category and weight status among children living in low-income communities. Furthermore, it is unknown whether dietary quality mediates the positive relationship between highly processed food consumption and weight status that has been observed in some studies (Juul et al., 2018; Louzada et al., 2015). To address these gaps in the literature, the objective of this study was to investigate the independent associations between food consumption by processing category, dietary quality and weight status and to examine the role of dietary quality as a mediator in the relationship between processed food intake and weight status in a low-income, ethnically diverse sample of children. Based on the literature presented, we hypothesized that highly processed food intake would be inversely associated with dietary quality and positively associated with body mass index, and that dietary quality would mediate the association between intake and weight status.

2. Methods

2.1. Study population

This analysis used baseline data from an observational study examining the role of the Summer Food Service Program on excess summer weight gain in children aged 6–12 years. Briefly, 137 children were recruited from two low-income communities in the Northeastern region of the U.S. for participation during summer 2017 (n = 67) or 2018 (n = 70). Baseline assessments took place during May or June of 2017 and 2018. To be eligible, children, aged 6–12 years, had to qualify for free- or reduced-price school meals, be able to speak English or Spanish, and have no extended travel plans for the summer. Children were eligible to participate for one summer only. Parents or caregivers provided informed consent and participants age eight or older provided informed assent. Children with incomplete data (n = 6) were dropped from analysis, for a final sample size of 131 children. The study protocol was approved by the Institutional Review Board at Tufts University.

2.2. Demographics

Socio-demographic characteristics were collected at baseline visits via parent/caregiver-completed questionnaire on child date of birth, sex, race/ethnicity, National School Breakfast Program and National School Lunch Program participation, and maternal education.

2.3. Anthropometrics

Trained research assistants measured height and weight, in triplicate, at baseline. Child weight was measured in street clothes, without shoes, to the nearest 0.1 kg using a calibrated digital scale (Tanita BWB 800; Tanita Corporation of America, Inc., Arlington Heights, IL, USA). Height was measured to the nearest millimeter using a portable stadi-ometer (Model 214, Seca Weighing and Measuring Systems, Handover, MD). BMI-for-age percentile and BMI-for-age z-scores (BMI-z) were calculated based on the Centers for Disease Control and

Prevention (CDC) standards (Kuczmarski et al., 2002) and weight categories were defined according to CDC cutpoints ("CDC Growth Charts: United States," 2000).

2.4. Dietary assessment

Diet was assessed via three 24-h dietary recalls collected on non-consecutive days, including two weekdays and one weekend day. Trained research staff conducted the interviews via telephone in English or Spanish using Nutrition Data Systems for Research (NDSR) version 2018 ("Nutrition Data Systems for Research," 2018). NDSR uses a multiple pass methodology to collect detailed information on each food and beverage item consumed by eating occasion over the past 24-h period (Feskanich, Sielaff, Chong, & Bartsch, 1989). For children under ten years, recalls were completed by a parent or caretaker with assistance from the child, while children ten years and older completed interviews on their own with input from the parent/caregiver as needed.

To assess dietary quality, Healthy Eating Index 2015 (HEI-2015) scores were calculated for each 24-h diet recall using SAS code developed by NDSR (Krebs-Smith et al., 2018; "SAS," 2018). This method is analogous to the simple HEI scoring algorithm provided by the National Institute of Health ("The Healthy Eating Index"). The HEI-2015 includes thirteen components that reflect the key recommendations in the 2015–2020 Dietary Guidelines for Americans (DGA) ("2015–2020 Dietary Guidelines for Americans. 8th Edition," December 2015). Component scores are summed to calculate a total HEI-2015 based on a scale from 0 to 100, with higher scores reflective of better adherence to the DGA and resulting higher dietary quality. HEI-2015 scores were analyzed by day, rather than averaged across participant, to retain information concerning differences in dietary quality on weekends compared to weekdays.

2.5. Classification of foods based on degree of processing

Food items were coded according to the extent and purpose of industrial processing using methods outlined by Poti et al. (Table 1) (Poti et al., 2015), a framework that was found to have the highest inter-rater reliability among processing classification systems used in the U.S (Bleiweiss-Sande et al., 2019). According to this classification system, "unprocessed and minimally processed" foods (UPF) are single-ingredient products with no or slight modification; "basic processed" foods (BPF) include single food components for use in cooking or items processed for preservation without added ingredients; "moderately processed" foods (MPF) are described as UPFs or BPFs with the addition of flavor additives or 100% whole grain products with no added sweeteners or fats and, "highly processed" foods (HPF) are multi-ingredient industrially formulated mixtures, including stand-alone products as well as condiments and sauces (Poti et al., 2015).

Foods were coded using the NDSR ingredients file (output file 1), which disaggregates foods into constituent ingredients where possible (e.g. an assembled turkey sandwich would consist of whole grain bread, turkey, lettuce, mustard and mayonnaise, with each ingredient coded separately). In some cases, the ingredients for industrially-produced products included items such as "water, lost in evaporation process" and "water, used in commercial manufacturing." These items occurred in small or negative gram amounts, so were dropped from the sample (n = 302). A total of 9,070 foods were used in analyses.

All foods were coded independently by two researchers (author 1 and 5), and discrepancies were discussed until a consensus was reached. Processing level was operationalized as percentage of calories from each processing level (UPF, BPF, MPF or HPF) per day of recall.

2.6. Analysis

Hypotheses were specified before data collection began and an analytic plan was specified a priori. All analyses were performed using SAS 9.4 ("SAS," 2018) and Stata Statistical Software ("Stata Statistical Software," 2018). Univariate statistics were used to describe the sample. To assess the relationship between processed food intake and BMI-z score, multivariate linear regression was used with percentage of calories from UPF, BPF, MPF and HPF as explanatory variables in separate models. To account for intra-child correlations between food recall days, the analysis was recast as a survey by designating each child as a primary sampling unit and each day of recall as a case. This approach allows the dependent variable (BMI-z) to remain constant in each cluster, while also allowing us to account for differences in dietary intake patterns on week vs. weekend days. To maintain consistency between models, this method was also used to examine the relationship between processed food consumption and HEI-2015 score. A sensitivity analysis was performed to determine whether a standard repeated measures approach yielded different results from a survey approach. Previous literature points to differences in weekday versus weekend eating patterns (Haines, Hama, Guilkey, & Popkin, 2003; Hanson & Olson, 2013; Hart, Raynor, Osterholt, Jelalian, & Wing, 2011). To account for this, 24-h recalls were weighted by day of the week, such that weekdays were assigned a weight of five out of seven, and weekends were assigned a weight of two out seven. Additional models were run to determine whether equal weighting of days yielded significantly different estimates.

A priori, we hypothesized a positive association between processing level and BMI-z in this sample. Therefore, we sought to determine whether HEI-2015 mediated the relationship between processed food intake and BMI-z score using structural equation modelling, retaining the same survey weights and cluster identification as described above. Covariates including age, sex, race/ethnicity, School Breakfast Program and National School Lunch Program participation and maternal education were tested in all models and final models were established using backwards elimination (Dunkler, Plischke, Leffondre, & Heinze, 2014).

3. Results

Children with incomplete demographic, anthropometric or dietary data were dropped from the analysis (n = 6) for a final sample size of 131 (mean age = 9.3 years, SD = 1.9; 58% male). The majority were Hispanic (73%), eligible for free versus reduced-price school meals (92%) and had a mother with an education level of high school or less (59%). A little under half of children (43%) had overweight or obesity (Table 2). As shown in Table 3, the overall mean HEI-2015 score was 49.9 out of 100 (sd ± 13.4). Mean HEI-2015 score was higher during the week [51.5, 95% CI (49.8, 53.2)] compared to weekends [46.5, 95% CI (44.4, 48.7)]. The majority of children's energy was derived from HPF (39.8%) followed by UPF (27.7%). The percentage of calories from foods by processing level did not vary significantly between weekdays and weekend.

3.1. Relationship between percentage of calories by processing level and HEI-2015

Results of unadjusted and adjusted linear regression models for the association between percentage of calories from processing level and HEI-2015 score are presented in Table 4. After controlling for maternal education and participation in school meals, a 10% increase in energy from HPF was associated with a 2.0 [95% CI (−2.7, −1.2)] point decrease in HEI-2015 score. In contrast, a 10% increase in energy from UPF was associated with a 3.0 [95% CI (2.1, 3.8)] point increase in HEI-2015 score in the adjusted model. Associations between basic and moderately processed foods and HEI-2015 score were not statistically significant.

3.2. Relationship between percentage of calories by processing level and BMI-z

Results of unadjusted and adjusted linear regression models for the association between percentage of calories from processing level and BMI-z score are presented in Table 5. After adjusting for sex, SBP and NSLP participation, there was no significant relationship between percentage of calories consumed by processing level and BMI-z score.

Given this null relationship, an in-depth analysis of HEI-2015 as a mediator in this relationship was irrelevant. Results of preliminary mediation analyses performed are presented in Table 6 (online supplementary).

4. Discussion

This analysis using dietary data collected from a low-income, ethnically diverse sample of children shows that greater intake of HPFs is associated with lower dietary quality while a greater intake of UPFs has a positive association with dietary quality. Together, these results offer insight into complementary approaches for improving dietary quality in child populations through reducing HPF availability and consumption and/or encouraging UPF consumption. Further, in this sample, we did not identify significant relationship between processed food intake and weight status. To our knowledge, this is the first study to examine associations between consumption of foods from all processing levels, dietary quality and weight status in a sample of children from low-income households.

Our results suggest that the majority of energy consumed by this population was derived from HPFs, with children consuming roughly 40% of energy from the highest processing category. This estimate is similar to one based on child dietary intake data from the National Health and Nutrition Examination Survey (NHANES) 2003–2008 by Eicher-Miller et al., which found that ready-to-eat-processed foods contributed 34.8% of daily energy intake (Eicher-Miller, Fulgoni, & Keast, 2015). Our results also support that 27.7% of daily energy intake was derived from UPFs, compared to 13.3% in the study by Eicher-Miller et al. Comparability between studies is somewhat limited by the fact that we used a different system for classifying processed foods, and given that our sample was youth from predominately low-income and minority backgrounds. However, they do suggest that UPF consumption has increased over the past decade while that of HPF has remained stable. This is supported by a report from the Pan American Health Organization, which shows that while North America is the highest consumer of HPFs globally, growth between 2000 and 2013 was minimal (2.3%) in the U.S. as compared to global averages (43.7%) ("Ultra-processed food and drink products in Latin America: Trends, impact on obesity, policy implications," 2015). This substantial increase is largely due to growth in middle and lower-income countries.

Consistent with the results from this study, related research has demonstrated an inverse association between highly processed food consumption and dietary quality. A study of national food purchase data from 2000 to 2012 in the U.S. found that households were more likely to exceed recommendations for saturated fat, sugar and salt intake for HPF compared to less-processed food purchases (Poti et al., 2015), while an analysis of NHANES dietary recalls showed an association between HPF and consumption of added sugars (Martinez Steele et al., 2016). Evidence from Columbia (Cornwell et al., 2017) and Brazil (Bielemann, Motta, Minten, Horta, & Gigante, 2015) has demonstrated lower nutritional profiles among children and young adults, respectively, who ate higher amounts of HPFs. Using national food consumption data, a more recent study from Brazil showed a direct association between highly processed food consumption and an unhealthful dietary pattern (Louzada et al., 2017). Average diet quality in this sample was 49.9 out of 100, which is lower than the national average for children ages 6–11 years in the U.S. (53.0) (United States Department of Agriculture, 2019). This is consistent with evidence that children from lower socio-economic status backgrounds have lower diet quality, which may increase the risk of adverse health outcomes during childhood or later in life (Fahlman, McCaughtry, Martin, & Shen, 2010; Kirkpatrick, Dodd, Reedy, & Krebs-Smith, 2012; Ranjit et al., 2015). Together with the research mentioned above, our findings support the conclusion that limiting highly processed foods in children's diets will improve overall dietary quality.

Our analysis does not support an association between processed food consumption and BMIz in children, a finding that is not unique. A study of adults in the United Kingdom found an inverse association between HPF consumption and dietary quality, but not obesity (Adams & White, 2015). Similarly, a longitudinal analysis of 1035 adolescents from Brazil found that those in the top quartile of HPF had lower intake of fruits and vegetables, as well as a lower BMIz at baseline and follow-up (Cunha, da Costa, da Veiga, Pereira, & Sichieri, 2018). Children in the top quartile of HPF consumption also had higher physical activity levels, which may help to explain these unexpected relationships (Cunha et al., 2018). The authors suggest that obesity may be more closely related to quantity rather than quality of food consumption; this hypothesis is supported by interventions that found no change in obesity when high energy-dense foods are displaced by fruits and vegetables (Bayer, Nehring, Bolte, & von Kries, 2014; Kaiser et al., 2014).

In contrast, a small body of evidence from Brazil and Sweden suggests that over-consumption of highly processed foods may be associated with obesity in both adults (Canella et al., 2014; Juul et al., 2018; Louzada et al., 2015; Silva et al., 2018) and children (Canella et al., 2014; Louzada et al., 2015). Further evidence points to an association between highly processed food intake, cardiovascular disease (Appannah et al., 2015; Rauber et al., 2015; Vitolo & Rauber, 2016) and metabolic syndrome in children (Tavares et al., 2012; Rinaldi et al., 2016), conditions that are often associated with obesity. Researchers have hypothesized that HPF consumption impacts body weight by increasing added sugars, fats and total calorie intake, and displacing foods high in fiber, protein and micronutrients (Fardet et al., 2015; Mendonca et al., 2016; Monteiro, 2009). Several studies have examined associations between specific food groups considered to be HPFs, finding positive associations between sugar-sweetened beverages (Grimes, Riddell, Campbell, & Nowson, 2013; Malik, Pan, Willett, & Hu, 2013), a Western dietary pattern and excess body weight (Poti, Duffey, & Popkin, 2014). A recent randomized controlled trial of the effects of highly or "ultra-processed" versus unprocessed diets on energy intake in overweight adults found that participants gained weight during the ultra-processed diet (0.8 ± 0.3 kg, $p = 0.01$) and lost weight during the unprocessed diet (1.1 ± 0.3 kg, $p = 0.001$) (Hall et al., 2019). Further research is needed to determine the mechanisms responsible for the observed outcomes. It is also important to prospectively study the effects of food consumption by processing category in children.

It is possible that the relative homogeneity of the present study's population played a role in the observed non-significant results concerning processed food intake and obesity. First, over 92% of the sample qualified for free school meals, a measure of household economic status, and the entire sample was eligible for either free or reduced-price lunch by design. Low-income neighborhoods tend to have a higher concentration of convenience stores and fast food restaurants, which sell energy-dense, nutrient poor foods, and limited access to supermarkets (Larson, Story, & Nelson, 2009). Thus, families in low-socioeconomic status neighborhoods may be more likely to buy highly refined, energy-dense foods due to issues of food access as well as cost (Ranjit et al., 2015). Indeed, several researchers have posited that convenience is a key factor in promoting excess consumption of certain HPFs (Monteiro et al., 2017; Poti et al., 2015). Second, the prevalence of overweight and obesity in this sample was higher than national averages. Specifically, 33.8% of youth had obesity, compared to 18.5% nationally, and 9.2% had overweight. Evidence supports that under-reporting is more frequent among individuals with overweight and obesity (Suissa, Benedetti, Henderson, Gray-Donald, & Paradis, 2019; Yamaguchi et al., 2016), such that associations between self-reported dietary intake and weight status may be biased (Subar et al., 2015). Accordingly, a similar analysis should be done in a nationally representative sample with more heterogeneity with respect to socio-economic and weight status.

This study has several limitations to consider. The study sample was composed of children from predominantly racial/ethnic minority and low-income backgrounds, and findings may not be generalizable to other populations in the U.S. As mentioned above, self-reported dietary data is subject to social desirability bias among others, which may lead to higher reported intakes of healthful foods and lower intakes of unhealthful foods, potentially underestimating the proportion of highly processed foods consumed. However, 24-h recalls are the gold-standard for self-report dietary data collection, and our estimate of highly processed food consumption in this population was comparable to results from similar studies (Martinez Steele et al., 2017; Poti et al., 2015). It is important to tailor study designs to processing level as the outcome of interest during all stages of the data collection process, such as ensuring that interviews request product brand names, information on flavorings and other additions, as well as establishing consistent methods for recording food items.

The main strengths of this study include use of 24-hr recalls for collecting dietary measures and objective measures for height and weight. The study is also strengthened by inclusion of a low-income and ethnic/minority youth sample, as this population is at the greatest risk of consuming highly processed diets and represents a particular challenge for collecting detailed dietary data (Ranjit et al., 2015; Singh, Siahpush, & Kogan, 2010). We were able to analyze foods based on their constituent ingredients, reducing potential for misclassification of the processing level of foods. While most analyses examining processed food consumption and obesity have utilized nationally representative datasets, this study looked specifically at a population of lower income, racial/ethnic minority children who are at a greater risk of obesity and associated health conditions.

5. Conclusions

This study contributes important findings concerning the role of processed foods in the diets of children from racially/ethnically diverse and lower-income backgrounds. Our findings demonstrate that greater intakes of highly processed foods are associated with lower dietary quality, while increased consumption of unprocessed or minimally processed food is associated with higher dietary quality. Our findings do not support an association between processed food consumption and weight status. However, future research should clarify these results through prospective study designs in similar populations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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List of abbreviations

BPF	Basic Processed Foods
DGA	Dietary Guidelines for Americans
HPF	Highly Processed Foods
MPF	Moderately Processed Foods
NDSR	Nutrition Data Systems for Research
UNC	University of North Carolina at Chapel Hill

UPF Unprocessed and Minimally Processed Foods

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Table 1

Category definitions and criteria for classifying foods and beverages based on degree of industrial food processing (Poti et al., 2015).

Category/definition	Examples
Unprocessed & minimally processed foods	
Single-ingredient foods with no or very slight modifications that do not change inherent properties of the food as found in its natural form.	Plain milk; fresh, frozen or dried plain fruit or vegetables; eggs, unseasoned meat; brown rice; honey, herbs and spices.
Basic processed foods	
Processed basic ingredients: single isolated food components obtained by extraction or purification using physical or chemical processes that change inherent properties of the food	Unsweetened fruit juice not from concentrate; whole grain pasta; oil, unsalted butter, sugar, salt.
Processed for basic preservation or precooking: single minimally processed foods modified by physical or chemical processes for the purpose of preservation or precooking but remaining as single foods.	Unsweetened fruit juice from concentrate; unsweetened/unflavored canned fruit, vegetables, legumes; plain peanut butter, refined grain pasta, white rice; plain yogurt.
Moderately processed foods	
Moderately processed for flavor: single minimally or moderately processed foods with addition of flavor additives for the purpose of enhancing flavor; directly recognizable as original plant/animal source.	Sweetened fruit juice, flavored milk; frozen French fries; salted peanut butter; smoked or cure meats; cheese, flavored yogurt, salted butter.
Moderately processed grain products: grain products made from whole-grain flour with water, salt, and/or yeast.	Whole grain breads, tortillas or crackers with no added sugar or fat.
Highly processed foods	
Highly processed ingredients: multi-ingredient industrially formulated mixtures processed to the extent that they are no longer recognizable as their original plant/animal source and consumed as additions.	Tomato sauce, salsa, mayonnaise, salad dressing, ketchup.
Highly processed stand-alone: multi-ingredient industrially formulated mixtures processed to the extent that they are no longer recognizable as their original plant/animal source and not typically consumed as additions.	Soda, fruit drinks; frozen vegetable dishes with sauce; formed lunchmeats; breads made with refined flours; pastries; ice-cream, processed cheese; candy.

Table 2

Demographic characteristics, children participating in the Summer Food Service Study (N = 131).

Sex, n (%)		
Male	76	(58.0)
Female	60	(45.8)
Age (years), mean (sd)	9.3	(1.90)
Race, n (%)		
Non-Hispanic black	10	(7.6)
Non-Hispanic white	6	(4.6)
Hispanic	95	(72.5)
Multiracial/Asian/other	20	(15.3)
Child free/reduced price lunch eligibility, n (%)		
Free	121	(92.4)
Reduced	10	(7.6)
Mother's education level, n (%)		
High school degree or less	77	(58.8)
Some college or associate's degree	32	(24.4)
College degree or above	27	(20.6)
Weight status, n (%)		
Underweight[a]	0	0.0
Normal weight[b]	75	(57.3)
Overweight[c]	12	(9.2)
Obese[d]	44	(33.8)

[a]BMI-for-age percentile < 5th.

[b]BMI-for-age percentile ≥ 5th and < 85th.

[c]BMI-for-age percentile ≥ 85th and < 95th.

[d]BMI-for-age percentile ≥ 95th.

Table 3

Dietary characteristics by weekday vs. weekend, children participating in the Summer Food Service Study (N = 131).

	Overall (mean, sd)		Weekdays (mean, se)	Weekends (mean, se)
Daily energy intake (kcal)	1,411.2	(539.9)	1,391.1 ± 32.7	1,454.9 ± 54.2
Healthy Eating Index-2015 total score	49.9	(13.4)	51.5 ± 0.9	46.5 ± 1.1
Daily kilocalories by processing level (%)[a]				
Unprocessed/minimally	27.7	(15.2)	28.1 ± 0.9	26.6 ± 1.5
Basic processed	16.7	(13.2)	16.1 ± 0.8	18.0 ± 1.3
Moderately	15.8	(13.4)	16.5 ± 0.8	14.4 ± 1.2
Highly	39.8	(17.2)	39.2 ± 1.1	40.9 ± 1.5

[a]As defined in Poti et al. (2015).

Table 4

Results of linear regression models quantifying the relationship between percent of calories from processing level (Poti et al., 2015) per intake day[a] with Healthy Eating Index 2015 score among children participating in the Summer Foodservice Study (N = 131).

	Unadjusted					**Adjusted[b]**				
	β	**SE**	***P***	**95% CI**		**β**	**SE**	***P***	**95% CI**	
Unprocessed	0.307	0.04	**0.00**	0.223	0.390	0.297	0.04	**0.00**	0.211	0.383
Basic	0.031	0.07	0.63	−0.098	0.161	0.002	0.05	0.97	−0.100	0.104
Moderately	−0.059	0.07	0.37	−0.189	0.070	−0.066	0.06	0.40	−0.187	0.054
Highly	−0.226	0.04	**0.00**	−0.300	−0.152	−0.196	0.04	**0.00**	−0.269	−0.122

[a]Consumption data from three, non-consecutive 24-hr recalls, weighted by weekday vs. weekend.

[b]Adjusted for maternal education level and days of National School Breakfast and National School Lunch Program participation.

Table 5

Results of linear regression models quantifying the relationship between percent of calories from processing level (Poti et al., 2015) per intake day[a] with age- and sex-standardized body mass index score among children participating in the Summer Foodservice Study (N = 131).

	Unadjusted					Adjusted[b]				
	β	**SE**	***p***	**95% CI**		**β**	**SE**	***P***	**95% CI**	
Unprocessed	0.0053	0.01	0.31	−0.0049	0.0155	0.0069	0.00	0.13	−0.0019	0.0157
Basic	0.0001	0.00	0.99	−0.0096	0.0090	−0.0035	0.00	0.43	−0.0121	0.0052
Moderately	−0.0048	0.01	0.34	−0.0147	0.0051	−0.0068	0.00	0.13	−0.0157	0.0020
Highly	−0.0012	0.00	0.80	−0.0107	0.0083	0.0006	0.00	0.87	−0.0068	0.0080

[a]Consumption data from three, non-consecutive 24-hr recalls, weighted by weekday vs. weekend.

[b]Adjusted for sex, days of National School Breakfast and National School Lunch Program participation.