AJCN. First published ahead of print April 26, 2017 as doi: 10.3945/ajcn.116.150029.

Diet quality of US adolescents during the transition to adulthood: changes and predictors[1,2]

Leah M Lipsky,[3] Tonja R Nansel,[3] Denise L Haynie,[3] Danping Liu,[4] Kaigang Li,[5] Charlotte A Pratt,[6] Ronald J Iannotti,[7] Katherine W Dempster,[3] and Bruce Simons-Morton[3]*

[3]Health Behavior Branch and [4]Biostatistics and Bioinformatics Branch, Division of Intramural Population Health Research, *Eunice Kennedy Shriver* National Institute of Child Health and Human Development, Bethesda, MD; [5]Department of Health and Exercise Science, Colorado State University, Fort Collins, CO; [6]Division of Cardiovascular Sciences, National Heart, Lung and Blood Institute, Bethesda, MD; and [7]The CDM Group, Bethesda, MD

ABSTRACT

Background: Influences on diet quality during the transition from adolescence to adulthood are understudied.

Objective: This study examined association of 3 diet-quality indicators—Healthy Eating Index-2010 (HEI), Whole Plant Foods Density (WPF), and Empty Calories (EC; the percentage of calories from discretionary solid fat, added sugar and alcohol)—with lifestyle behaviors, baseline weight status, and sociodemographic characteristics in US emerging adults.

Design: Data come from the first 4 waves (annual assessments) of the NEXT Plus Study, a population-based cohort of 10th graders enrolled in 2010 (n = 566). At each assessment, participants completed 3 nonconsecutive 24-h diet recalls, wore accelerometers for 7 d, and self-reported meal practices and sedentary behaviors. Self-reported sociodemographic characteristics were ascertained at baseline. Generalized estimating equations examined associations of time-varying diet quality with baseline weight status and sociodemographic characteristics and time-varying lifestyle behaviors.

Results: Diet quality improved modestly from baseline (mean ± SE: HEI, 44.07 ± 0.53; WPF, 1.24 ± 0.04; and EC, 35.66 ± 0.55) to wave 4 for WPF (1.44 ± 0.05, $P < 0.001$) and EC (33.47 ± 0.52, $P < 0.001$), but not HEI (45.22 ± 0.60). In longitudinal analyses, higher HEI and lower EC scores were observed in Hispanic compared with white participants. Better diet quality was associated with greater moderate-to-vigorous physical activity, more frequent breakfast and family meals, less frequent fast food and meals during television viewing, and shorter durations of television viewing, gaming, and online social networking. Diet-quality indicators were not consistently associated with time-varying physical inactivity, baseline weight status, or sociodemographic characteristics.

Conclusions: Diet quality of emerging adults in the US remained suboptimal, but some aspects improved marginally over the 4-y study period. Meal contexts and sedentary behaviors may represent important intervention targets. There is substantial room for improvement in diet quality in all sociodemographic subgroups. This trial was registered at clinicaltrials.gov as NCT01031160. *Am J Clin Nutr* doi: 10.3945/ajcn.116.150029.

Keywords: adolescents, young adults, diet quality, lifestyle behaviors, physical activity, media use, eating behaviors

INTRODUCTION

US youth consume inadequate amounts of recommended food groups, including fruit, vegetables, and whole grains, and excessive amounts of sodium, refined grains, solid fat, and added sugar (1). Aspects of diet quality are particularly suboptimal in adolescents relative to younger children (2). Adolescents consume ∼10% of the recommended amount of greens and beans and ∼50% of the recommended amount of total vegetables and whole grains. Consumption of energy from empty calories (EC; solid fat, added sugar, and excessive alcohol) is ∼50% more than the recommended limit (2). Emerging adulthood, the transition between adolescence and adulthood, is recognized as a critical developmental period of increasing autonomy (3) during which lifelong health behaviors are established (4). Understanding diet-quality trajectories and identifying modifiable influences during this developmental stage is warranted given the initiation of adverse cardiometabolic health trajectories in early adulthood (5) and the importance of diet quality for chronic disease and mortality risk (6, 7).

Lifestyle behaviors, such as meal practices and sedentary behaviors, may affect diet quality through their influence on the social and environmental contexts of eating occasions. In younger children and older adults, cross-sectional studies show that better diet quality is associated with more frequent breakfasts (8) and family meals (9), whereas poorer diet quality is related to greater fast food intake (10) and television viewing (11). Associations of diet quality with physical activity, inactivity, and sedentary

[1] Supported in part by the intramural research program of the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (contract HHSN275201200001I); the National Heart, Lung and Blood Institute; the National Institute on Alcohol Abuse and Alcoholism; and the Maternal and Child Health Bureau of the Health Resources and Services Administration, with supplemental support from the National Institute on Drug Abuse.

[2] Supplemental Table 1 is available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of contents at http://ajcn.nutrition.org.

*To whom correspondence should be addressed. E-mail: lipskylm@mail.nih.gov.

Received December 6, 2016. Accepted for publication March 21, 2017. doi: 10.3945/ajcn.116.150029.

behaviors other than television viewing have received less attention in the literature. Physical activity declines between childhood and early adolescence (12), and recent data indicate that <10% of older adolescents meet guidelines of ≥60 min/d of moderate-to-vigorous physical activity when assessed objectively (13). In contrast, adolescents devote more time to media use than any behavior other than sleep, and usage of the various types of media increased considerably (e.g., 19% for television content, 230% for computer use) between 1999 and 2009 (14). Additionally, ~75% of adolescents have access to a smartphone (with only 12% having no access to a cell phone) (15), almost double the proportion owning a cell phone in 2004. Investigating how these behaviors relate to diet quality in US emerging adults may inform intervention strategies for improving diet quality in this population.

Previous research on behavioral correlates of diet quality has focused on intake of specific nutrients (4), food groups (16), or overall energy intake (17). Fewer studies have examined correlates of overall diet quality (10, 18), which give a more holistic representation of dietary intake, taking into account that diet involves a combination of interrelated nutrients and foods (19). Moreover, research in this area has been primarily cross-sectional (10) and is based on geographically limited US samples (16), indicating the need for more generalizable, prospective studies. The purpose of this study was to examine behavioral correlates and baseline predictors of diet quality over the transition to adulthood in a contemporary, diverse national cohort of US 10th graders.

METHODS

Sample

The NEXT Generation Health Study is a nationally representative cohort of 2785 10th graders recruited from 81 public, private, and parochial schools in the United States by using a multistage sampling design stratified by census division (20). The participant flow diagram is presented in **Figure 1**. The NEXT Plus subsample was systematically sampled from among NEXT participants by using geographic cluster sampling to identify 20 urban, suburban, and rural communities in each census division, from which 44 schools were selected. Two classrooms within these schools were randomly selected, from which 7 normal-weight [BMI (in kg/m^2) percentile ≥5 to <85] and 7 overweight (BMI percentile ≥85) NEXT participants were approached to participate in NEXT Plus to provide additional assessments. An approximately equal number of normal-weight (n = 286) and overweight (n = 281) participants were enrolled (73% response rate); 1 participant refused to complete NEXT Plus assessments after enrollment, leaving 566 NEXT Plus participants for this analysis. Students with no blood conditions associated with increased bleeding risk were eligible to participate in NEXT Plus. Data from the first 4 waves of NEXT Plus were included in this analysis. Participants were assessed annually [wave 1 = 10th grade (2010), wave 2 = 11th grade, wave 3 = 12th grade, wave 4 = 1 y after high school] during the spring semester, with 81% retention in wave 4. Parental informed consent and youth assent were obtained at baseline, and youth informed consent was obtained on reaching 18 y of age. Procedures were approved by the Institutional Review Board of the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development.

Diet assessment

Participants completed 3 nonconsecutive 24-h diet recalls annually using the Automated Self-Administered 24-Hour Recall (ASA24)[8] developed by the National Cancer Institute. The ASA24 is a web-based tool for collecting self-administered 24-h diet recalls modeled on and validated against the interviewer-administered Automated Multiple Pass Method 24-h recall (21, 22). Participants were prompted on 2 weekdays and 1 weekend day to complete their recall for the day before and received $10 for each completed recall for a total of $30 after completing 3 recalls; recalls occurred over approximately the same period during which participants completed the surveys and wore accelerometers (between 3 wk before and 1 wk after). The ASA24 prompts participants to record details regarding food preparation, brands, portion size, and additions to assigned food codes from the USDA Food and Nutrient Database for Dietary Surveys. This information is used to provide estimates of macronutrient, micronutrient, food categories, and USDA Food Patterns Equivalents Database food groups. In accordance with the method used for excluding records with implausible energy intakes in the Nurses' Health Study, diet data from participants were excluded if estimated mean daily energy intakes were <500 or ≥5000 kcal/d. This method produces similar associations of dietary predictors and health outcomes as more complicated methods, such as the Goldberg method or the predicted total energy expenditure method (23). The upper limit was extended in consideration for the age and sex characteristics of the NEXT Plus sample. Approximately 4% of the recalls were excluded; intakes were multiply imputed as described below. Participants were not asked to complete the dietary supplements module.

Diet quality indicators

Scores on 3 a priori diet-quality indicators, the Healthy Eating Index-2010 (HEI), Whole Plant Food Density (WPF), and EC, were calculated from diet recall data. This set of indicators was selected to reflect both overall diet quality (HEI) as well as more specific overall measures of dietary factors that are most notably underconsumed or overconsumed relative to recommendations (WPF and EC, respectively). The HEI reflects conformance to the 2010 US Dietary Guidelines for Americans, with higher scores indicating greater conformance (24). The total score ranges from 0 to 100 and is calculated by summing 12 component scores, each reflecting a specific aspect of the Dietary Guidelines for Americans. Component scores are truncated, with maximum scores (5, 10, or 20, depending on the component) assigned for intakes meeting the least stringent standard and prorated scores for intakes not meeting the minimum standard. Component scores are referred to as "adequacy components" (total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein, seafood and plant proteins, and fatty acids) or "moderation components" (refined grains, sodium, and EC) and are calculated on a per-1000-kcal or percentage-of-calories

[8] Abbreviations used: ASA24, Automated Self-Administered 24-Hour Recall; EC, Empty Calories; GEE, generalized estimating equation; HEI, Healthy Eating Index-2010; MVPA, moderate-to-vigorous physical activity; WPF, Whole Plant Foods Density.

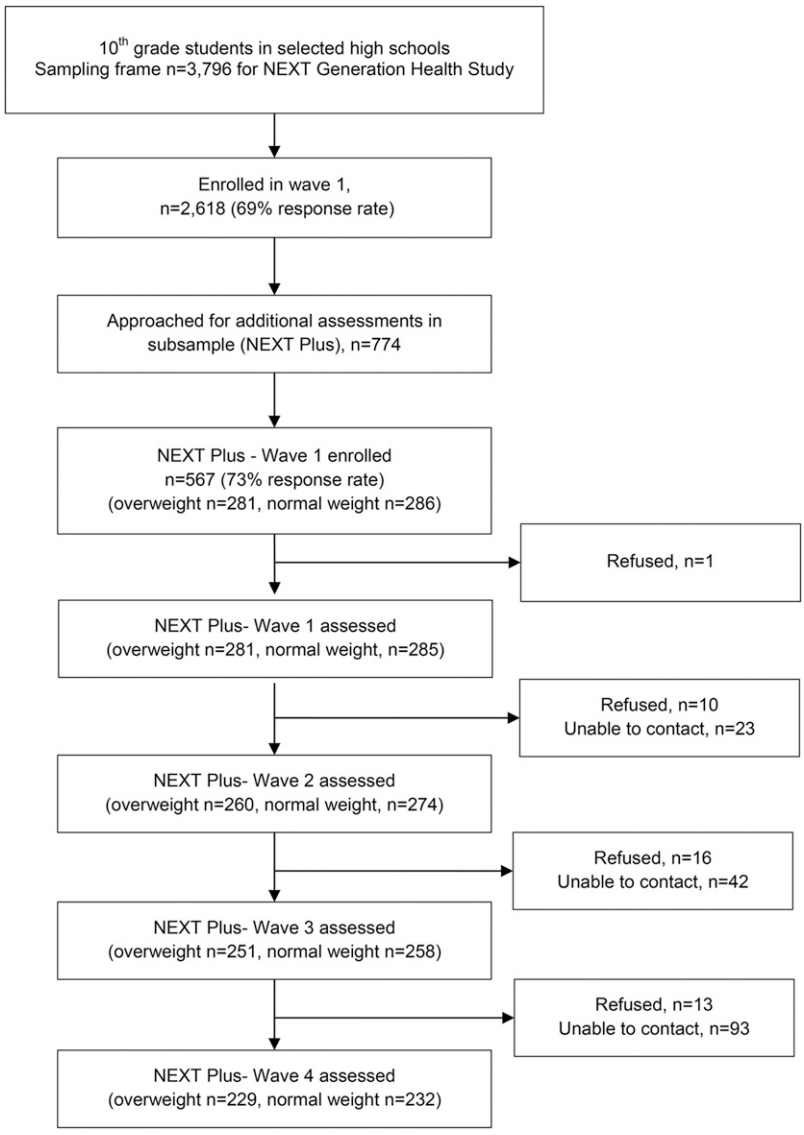

FIGURE 1 Participant flowchart.

basis to enable comparisons of diet quality across individuals with varying energy requirements. The measure was developed for surveillance of all individuals to whom the USDA Food Patterns apply, including children ≥2 y of age. The measurement's reliability and validity have been established after extensive evaluation, including verification that it is internally consistent, distinguishes meaningful differences in diet quality between individuals, assesses diet quality independent of energy intake, and reflects multiple dimensions of diet quality (25).

WPF (26) is a continuous measure calculated as the sum of cup or ounce equivalents of whole plant foods (whole grains, whole fruit, vegetables, legumes, nuts, and seeds) as based on the disaggregated food groupings in the USDA Food Patterns Equivalents Database per 1000 kcal energy consumed. The measure was developed to reflect the intake of plant foods. Minimum recommendations include 3-cup or 3-oz equivalents per 1000 kcal whole grains, fruits, and vegetables combined (24); no specific guidelines exist for intake of nuts and seeds. The WPF measurement has been correlated with cardiovascular biomarkers in the general US population (26).

EC was examined as an indicator of discretionary intake (i.e., foods that contribute energy but nominal nutritional value to the diet). The measurement, based on the EC component of the HEI, represents the proportion of energy intake from added sugars, discretionary solid fat, and excess alcohol (24). In contrast to the HEI-2010 EC component, which is a truncated score, we investigated EC as a continuous measurement ranging from 0% to 100% of energy intake. We additionally calculated EC in units of total kcal for descriptive purposes. Recommendations specify that EC should not exceed 19% of energy intake (24).

Lifestyle behaviors

Objectively measured physical activity

Objectively measured physical activity was assessed annually; details have been described elsewhere (13). Briefly, participants were asked to wear an accelerometer (GT3X; ActiGraph) on their

hip for ≥10 h/d for 7 consecutive days, except during swimming or bathing. Data from participants with ≥500 recorded min/d for 4 d were included. ActiLife (ActiGraph) was used to calculate the average daily number of minutes of moderate-to-vigorous physical activity (MVPA, defined as ≥2296 counts/min), and sedentary activity (defined as ≤100 counts/min) in accordance with published cutoffs (27).

Meal practices

Questions regarding meal practices on the annual survey were based on items from the multinational Health Behavior in School-Aged Children Study (28). Participants indicated past-week frequency of having breakfast ["How often do you usually have breakfast (more than a glass of milk or fruit juice)"], having family meals ("How often do you have an evening meal together with your mother or stepmother or father or stepfather," assessed waves 1–3 only), watching television during meals ("How often do you watch television during a meal at home," assessed waves 1–3 only), and eating fast food ("How often do you eat in a fast food restaurant"). Responses for family meals and television during meals included never, <1 time/wk, 1–2 d/wk, 3–4 d/wk, 5–6 d/wk, or every day. For fast food, response options included never, rarely (<1 time/mo), 1 time/mo, 2–3 times/mo, 2–4 d/wk, or ≥5 d/wk. For breakfast, participants reported separately for weekdays (response options included never and 1, 2, 3, 4, and 5 d) and weekend days [response options included never, 1 d of the weekend (Saturday or Sunday), and both weekend days (Saturday and Sunday)]. Responses were converted to represent the number of days per week by using the midpoint of the response option ranges (e.g., 1–2 d/wk was converted to 1.5). The maximum value for fast food frequency was 5, reflecting ≥5 d/wk.

Self-reported sedentary behaviors

Participants reported time spent watching television ["watch television (including videos or DVDs) or use a DVD player"], gaming ["play games on a computer or game console (Playstation, Xbox, GameCube, etc.)"], and social networking ["use a computer or cell phone for chatting online, internet, emailing, texting, tweeting, or similar social networking (other than for a job or school work)"] on the annual survey. Participants responded separately for weekdays and weekend days. Response options included none and ~0.5, ~1, ~2, ~3, ~4, ~5, ~6, or ~≥7 h/d and were converted to the number of hours per day (ranging from 0 to 7). Test-retest reliability in younger international samples for computer and television use has ranged from 0.54 to 0.81 (29, 30).

Baseline predictors

Sociodemographic characteristics

Participants self-reported sociodemographic characteristics at baseline, including sex, race/ethnicity (categorized as non-Hispanic white, non-Hispanic black, Hispanic, and other), and age. In addition, the Family Affluence Scale, an ordinal measurement ranging from 0 (low affluence) to 7 (high affluence), was calculated based on participant survey responses regarding household car and computer ownership, frequency of family vacations, and bedroom sharing (31). Parent education was ascertained during the consent process and categorized as high school graduate or General Education Development graduate, some post–high school education, and Bachelor's degree or more.

Anthropometrics

Baseline weight was measured by using a calibrated digital scale (Healthometer 489KL), with excess clothing, shoes, and additional items removed. Baseline height without shoes was measured by using a stadiometer (SECA). Baseline weight status was calculated according to CDC age- and sex-adjusted BMI percentile cutoffs (normal weight: BMI percentile ≥5 to <85; overweight: BMI percentile ≥85).

Statistical analysis

Multiple imputation by chained equations assuming missing at random (32, 33) was used for missing data. Generally, <10% of the data for the variables were missing, although because of loss to follow-up, missingness of the diet data reached 28% by wave 4. Fifty imputed datasets were generated by using IVEware (34). Datasets were analyzed separately and results combined by using Rubin's rule in StataSE version 14 (StataCorp LP).

First, by using unadjusted linear regression models with generalized estimating equation (GEE) with robust SE estimation, we estimated the mean values for each diet-quality indicator and lifestyle behavior over time (wave) and performed an overall test for time trend. Next, adjusted GEE models investigated whether baseline weight status and sociodemographic characteristics (age, sex, race/ethnicity, Family Affluence Scale score, parent education) predicted time-varying diet-quality indicators. Finally, the associations of diet-quality indicators with each time-varying lifestyle behavior (meal practices, physical and sedentary activity, and self-reported sedentary behaviors) were estimated by using separate, adjusted GEE models (controlling for baseline weight status and sociodemographic characteristics as in the previous models). Analyses of associations with watching television during meals and with family meals were restricted to waves 1–3 because these were not assessed at wave 4.

RESULTS

Just over half of the 566 participants were female; baseline age was 16.5 y (**Table 1**). By design, approximately half of the participants were normal weight, and the other half were overweight or obese at baseline. Over half of the sample was of racial-ethnic minority, and approximately two-thirds of the sample had parents with more than a high school or General Education Development diploma but less than a bachelor's degree. At baseline, mean duration of MVPA was <30 min/d, and sedentary activity duration exceeded 8 h/d. On average, participants skipped breakfast >2 d/wk and ate at a fast-food restaurant ≥1 d/wk. Participants reported using a computer or cell phone for social networking nearly 4 h/d, longer than the combined duration of the other sedentary behaviors.

Mean diet quality indicator scores changed modestly over waves 1–4 (**Table 2**). Minor improvements in diet quality, as indicated by an increase in the WPF score and a decrease in EC, were observed in wave 4 compared with wave 1. The HEI at wave 4 was not statistically significantly different from that at

TABLE 1
Baseline sociodemographics and lifestyle behaviors in the NEXT Plus study (n = 566, imputations = 50)

	Mean ± SE
Sociodemographics	
Female, %	54.6 ± 2.1
Age, y	16.5 ± 0.0
Weight status,[1] %	
Normal weight	51.0 ± 2.1
Overweight	22.8 ± 1.8
Obese	26.3 ± 1.9
Race/ethnicity, %	
Non-Hispanic white	44.9 ± 2.1
Non-Hispanic black	16.6 ± 1.6
Hispanic	33.9 ± 2.0
Other	4.6 ± 0.9
Family Affluence Score[2]	5.1 ± 0.1
Parent education, %	
≤High school graduate/GED[3]	36.1 ± 2.0
Some post-high school	40.5 ± 2.1
≥College degree	24.3 ± 1.8
Lifestyle behaviors	
Physical activity, h/d	
Moderate-to-vigorous physical activity	0.4 ± 0.0
Sedentary activity	8.3 ± 0.1
Meal practices, d/wk	
Breakfast	4.6 ± 0.1
Family meals	2.5 ± 0.1
Fast food	1.0 ± 0.1
Television during meals	3.3 ± 0.1
Sedentary behaviors, h/d	
Electronic gaming	1.2 ± 0.1
Social networking	3.9 ± 0.1
Television viewing	2.3 ± 0.1

[1] Normal weight: BMI percentile ≥5 to <85; overweight: BMI percentile ≥85 to <95; obese: BMI percentile ≥95.
[2] Validated scale ranging from 1 to 5; higher scores reflect greater affluence.
[3] GED, General Education Development.

wave 1. Unadjusted time-varying associations between the indicators are presented in the online supplemental material (**Supplemental Table 1**). As expected, HEI and WPF were positively associated; EC was inversely associated with HEI and WPF.

Baseline sociodemographic characteristics (sex, family affluence, and parent education) were not consistently associated with time-varying diet-quality indicators (**Table 3**), except that more favorable HEI and EC scores were observed in Hispanic relative to non-Hispanic white participants. WPF scores were greater in females than in males, but sex was not related to HEI or EC.

Results from models estimating associations of time-varying diet-quality indicators with time-varying lifestyle behaviors indicate that more MVPA was associated with higher HEI and WPF, whereas sedentary activity was not associated with any diet-quality indicator (**Table 4**). In contrast, meal practices and self-reported sedentary behaviors were consistently associated with diet quality. More frequent breakfast and family meals were associated with higher HEI and WPF scores and lower EC scores. Conversely, more frequent fast food, television viewing, and social networking were associated with lower HEI and WPF scores and higher EC scores. Similarly, more frequent television during meals was associated with lower HEI and WPF scores, whereas gaming was associated inversely with HEI and positively with EC.

DISCUSSION

To our knowledge, this is the first longitudinal study of overall diet quality and its association with time-varying lifestyle behaviors in US emerging adults. At baseline, this national cohort of US 10th graders consumed less than half the minimum recommended amount of whole plant foods and met less than half of minimum guidelines overall as indicated by an HEI score of <50. Intake of EC, accounting for nearly 36% of energy intake, equivalent to ~680 kcal/d, was nearly 75% greater than the recommended maximum intake. Diet quality remained well short of minimum guidelines but improved modestly during the transition to young adulthood with respect to WPF and EC. Few sociodemographic differences in diet quality over this 4-y period were observed. In contrast, diet quality over time was associated positively with breakfast and family meal frequency and negatively with frequency of fast food, watching television during meals, and self-reported sedentary behaviors.

Previous cross-sectional studies have shown that diet quality in adolescents is poorer than in younger children (1, 2) and older adults (1, 35). A prospective study of students in Minnesota assessed in 1999 and 2004 showed a decrease in fruit and vegetable intake and an increase in fast-food intake from childhood and young adolescence to older adolescence (16). Only one previous prospective study has reported change in dietary intake between adolescence and adulthood; the study, conducted in Norway in the 1990s, reported a decrease in fruit and vegetable intake and an increase in sweets and chocolate and in sugar-containing soft drinks between ages 14 and 21 y (36). This evidence, taken together with the current estimates showing stable or modest improvement in diet quality between ~16.5 and 20.5 y of age suggests adolescence may represent the nadir of diet quality over the life course.

We observed few associations of diet quality over time with baseline sociodemographic characteristics other than modestly more optimal HEI and EC scores in Hispanic participants relative to non-Hispanic whites. Similarly, several cross-sectional studies conducted after the year 2000 have shown better diet quality in Mexican-Americans and Hispanics relative to non-Hispanic black and non-Hispanic white children, adolescents, and adults (1, 37, 38). The null association of diet quality over time with family affluence is consistent with cross-sectional studies based on data from NHANES collected between 2001 and 2006 showing no association of diet quality with income in youth (1, 37, 38). In contrast, the findings are not consistent with disparities in diet quality observed in The Coronary Artery Risk Development in Young Adults Study, a prospective, multisite study conducted between 1985 and 2006 in adults aged 18–30 y at baseline (35). In that study, socioeconomic disparities in diet quality persisted but decreased over time which, taken in context with this data and other recent evidence, may indicate secular changes in the association of socioeconomic status with diet quality. It should be noted that the present study is not equipped to answer questions about the association of diet quality with severe poverty or food insecurity.

TABLE 2
Diet-quality indicator scores and lifestyle behaviors by wave in the NEXT Plus study, 2010–2014 (n = 566, imputations = 50)[1]

	Wave 1	Wave 2	Wave 3	Wave 4	P[2]
Diet-quality indicators					
HEI	44.07 ± 0.53	45.66 ± 0.52**	44.85 ± 0.54	45.22 ± 0.60	0.22
WPF	1.24 ± 0.04	1.31 ± 0.04	1.38 ± 0.06*	1.44 ± 0.05**	<0.001
EC	35.66 ± 0.55	34.02 ± 0.42**	33.32 ± 0.47**	33.47 ± 0.52**	<0.001
Physical activity, h/d					
Moderate-to-vigorous physical activity	0.42 ± 0.01	0.44 ± 0.01	0.45 ± 0.01	0.43 ± 0.02	0.67
Sedentary activity	8.34 ± 0.06	8.69 ± 0.06***	8.59 ± 0.06**	8.38 ± 0.08	0.92
Meal practices, d/wk					
Breakfast	4.55 ± 0.10	4.29 ± 0.10***	4.19 ± 0.10***	3.85 ± 0.11***	<0.001
Family meals	2.46 ± 0.08	2.20 ± 0.08***	1.98 ± 0.07***	—	<0.001
Fast food	1.02 ± 0.05	1.00 ± 0.05	1.04 ± 0.05	1.19 ± 0.05**	0.003
Television during meals	3.33 ± 0.12	2.98 ± 0.11**	2.86 ± 0.11***	—	<0.001
Sedentary behaviors, h/d					
Electronic gaming	1.17 ± 0.06	1.24 ± 0.06	1.12 ± 0.06	1.13 ± 0.07	0.32
Social networking	3.95 ± 0.11	3.73 ± 0.10*	3.80 ± 0.10	3.88 ± 0.10	0.72
Television viewing	2.27 ± 0.08	2.12 ± 0.07*	2.09 ± 0.06*	2.17 ± 0.07	0.19

[1] Values are means ± SEs. Estimates from linear GEEs predicting time-varying diet quality and lifestyle behaviors over time (no covariates). *·**·***Different from wave 1: *$P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. EC, Empty Calories (percentage of energy from added sugar, discretionary solid fats, and alcohol); GEE, generalized estimating equation; HEI, Healthy Eating Index-2010 (minimum: 0, maximum: 100; reflects conformance to 2010 Dietary Guidelines for Americans); WPF, Whole Plant Foods Density (continuous measure representing sum of cup or ounce equivalents per 1000 kcal of whole fruits, vegetables, legumes, nuts, and seeds).

[2] Overall time trend from GEE regression models.

Similarly, with respect to weight status, our findings are in line with those of a recent systematic review, which reported that a majority of studies (18 out of 26) observed null associations between diet-quality indexes and weight status in youth (39). Overall, these findings suggest that suboptimal diet quality is not exclusive to any of these population subgroups.

This study extends the literature on behavioral correlates of diet quality by examining a broad range of time-varying lifestyle behaviors and diet-quality indicators during an understudied developmental stage. Findings largely confirm those from previous studies showing associations of aspects of better diet quality with more frequent breakfast (8, 18) and family meals (40) and with less frequent television viewing during meals (41, 42), eating at fast-food restaurants (17, 43), and overall television viewing (11, 42, 44, 45). The consistency of these associations across a variety of age groups supports the plausibility of causality between the variables, although controlled intervention trials are necessary to confirm these observational findings.

The current findings have implications for understanding the associations of diet quality with objectively measured physical activity and self-reported sedentary behaviors. Time-varying MVPA was positively associated with more favorable time-varying HEI and WPF scores, consistent with previous studies showing positive associations of self-reported physical activity with several aspects of better dietary intake in adolescents and older adults (46, 47). Similarly, the inverse relations of television viewing with all diet quality indicators and of gaming with HEI and EC in this study are consistent with 2 prospective studies that reported inverse associations of these behaviors with aspects of diet quality (e.g., intake of fruits and vegetables, fast food, sugar-sweetened beverages, and energy-dense snacks) (44, 48). To our knowledge, the association of diet quality with social networking and other Internet use has not been examined previously. The inverse association of sedentary behaviors with diet quality may result from concomitant, passive consumption of unhealthy foods (49, 50) or the effects of exposure to marketing for energy-dense foods (51), the latter of which is common to all 3 sedentary behaviors examined herein (52). Our findings are consistent with these hypothesized pathways and suggest the importance of addressing suboptimal eating behaviors in these behavioral contexts.

Limitations of this study include the observational study design, which limits inferences regarding causality, and the reliance on self-reported data for several lifestyle behaviors (meal practices and sedentary behaviors), which may be susceptible to response bias. In addition, the Family Affluence Scale, although a validated measure of family socioeconomic status, may be only a proxy for household income, which may have affected our ability to detect associations with diet quality. Although the diet assessment method may not reflect long-term diet quality, it is likely to represent intake around the same time when other behaviors were assessed. Strengths of the study include the prospective design and repeated assessments of diet and several lifestyle behaviors as well as the use of multiple 24-h recalls for measuring dietary intake, an accelerometer for measuring physical activity, and measured height and weight for assessing weight status. The measurement of and adjustment for several hypothesized confounders are additional strengths. Finally, the use of multiple imputation reduces bias relative to complete case analysis, and the diverse, national sample supports the generalizability of the results.

These findings demonstrate that overall diet quality remains suboptimal across several population subgroups but improves

TABLE 3
Associations of time-varying diet quality with baseline weight status and sociodemographic characteristics in the NEXT Plus study, 2010–2014 (n = 566, imputations = 50)[1]

	Dependent variable					
	HEI		WPF		EC	
Independent variables	$\beta \pm$ SE	P	$\beta \pm$ SE	P	$\beta \pm$ SE	P
Baseline weight status[2] (reference: normal weight)						
Overweight	−0.49 ± 1.01	0.63	0.05 ± 0.08	0.57	0.55 ± 0.76	0.47
Obese	0.24 ± 0.86	0.77	0.12 ± 0.07	0.08	−0.62 ± 0.77	0.42
Sex (reference: male)	1.90 ± 1.05	0.07	0.24 ± 0.08	0.003	1.15 ± 0.84	0.17
Baseline age, y	−0.31 ± 0.72	0.67	0.004 ± 0.06	0.95	−0.06 ± 0.60	0.92
Height, cm	0.03 ± 0.06	0.64	0.0005 ± 0.005	0.91	0.04 ± 0.04	0.35
Race/ethnicity (reference: non-Hispanic white)						
Non-Hispanic black	−0.14 ± 0.95	0.88	−0.14 ± 0.08	0.09	−1.05 ± 0.84	0.21
Hispanic	3.82 ± 0.95	<0.001	0.07 ± 0.07	0.33	−2.52 ± 0.76	0.001
Other	2.51 ± 1.85	0.17	0.22 ± 0.16	0.18	−2.53 ± 1.66	0.13
Family Affluence Scale[3]	−0.19 ± 0.28	0.51	0.009 ± 0.02	0.70	0.33 ± 0.23	0.15
Parent education (reference: high school/GED)						
Post–high school	0.83 ± 0.89	0.35	0.10 ± 0.07	0.19	−0.70 ± 0.56	0.36
≥Bachelor's degree	0.43 ± 1.09	0.70	0.11 ± 0.09	0.20	−1.19 ± 0.90	0.19

[1] Estimates from linear generalized estimating equations examining associations of each dependent variable with all independent variables. EC, Empty Calories (percentage of energy from added sugar, discretionary solid fats, and alcohol); GED, General Education Development; HEI, Healthy Eating Index 2010 (minimum: 0, maximum: 100; reflects conformance to 2010 Dietary Guidelines for Americans); WPF, Whole Plant Foods Density (continuous measure representing sum of cup or ounce equivalents per 1000 kcal of whole fruits, vegetables, legumes, nuts, and seeds).
[2] Normal weight: BMI percentile ≥5 to <85; overweight; BMI percentile ≥85 to <95; obese: ≥95).
[3] Validated ordinal scale ranging from 1 to 7; higher scores reflect greater affluence.

modestly during emerging adulthood. Improved diet quality over time was consistently associated with several modifiable, time-varying behaviors, including more frequent family meals and breakfast, less frequent television during meals, and lower duration of television viewing, social networking, and gaming. The potential for age-related differences in developmental, social, and

TABLE 4
Time-varying associations of diet quality with physical activity, meal practices and sedentary behaviors in the NEXT Plus study, 2010–2014 (n = 566, imputations = 50)[1]

	Dependent variable					
	HEI		WPF		EC	
Independent variables	$\beta \pm$ SE	P	$\beta \pm$ SE	P	$\beta \pm$ SE	P
Physical activity, h/d						
Moderate-to-vigorous physical activity	1.99 ± 0.94	0.03	0.32 ± 0.09	0.001	−1.25 ± 0.78	0.11
Sedentary activity	0.32 ± 0.22	0.16	0.03 ± 0.02	0.13	−0.09 ± 0.18	0.60
Meal practices, d/wk						
Breakfast	0.69 ± 0.13	<0.001	0.06 ± 0.01	<0.001	−0.28 ± 0.11	0.02
Family meals	0.54 ± 0.19	0.005	0.05 ± 0.02	0.001	−0.35 ± 0.16	0.03
Fast food	−1.38 ± 0.25	<0.001	−0.11 ± 0.03	<0.001	1.01 ± 0.23	<0.001
Television during meals	−0.48 ± 0.12	<0.001	−0.04 ± 0.01	0.001	0.21 ± 0.11	0.06
Sedentary behaviors, h/d						
Television viewing	−0.60 ± 0.18	0.001	−0.06 ± 0.02	<0.001	0.58 ± 0.16	<0.001
Gaming	−0.44 ± 0.20	0.03	−0.01 ± 0.02	0.52	0.47 ± 0.17	0.006
Social networking	−0.55 ± 0.13	<0.001	−0.04 ± 0.01	<0.001	0.32 ± 0.11	0.003

[1] Estimates from generalized estimating equations examining associations of each dependent variable with each independent variable, separately. Covariates included time (wave) and time-varying height and baseline age, sex, weight status, race/ethnicity, Family Affluence Scale score, and parent education. EC, Empty Calories (percentage of energy from added sugar, discretionary solid fats, and alcohol); HEI, Healthy Eating Index-2010 (minimum: 0, maximum: 100; reflects conformance to 2010 Dietary Guidelines for Americans); WPF, Whole Plant Foods Density (continuous measure representing sum of cup or ounce equivalents per 1000 kcal of whole fruits, vegetables, legumes, nuts, and seeds).

environmental characteristics to modify the associations of behavioral factors with diet quality may be an important area for further study. Additionally, the strength of the observed associations of diet-quality indicators with different behavioral factors was similar, although we observed that the associations with MVPA and fast-food frequency tended to be stronger than for other behaviors, which may inform specific behavioral intervention targets. Overall, these findings suggest that there is widespread need for improvement in diet quality in emerging adults. The behavioral correlates identified in this study may represent attractive lifestyle modification targets for achieving this objective.

The authors' responsibilities were as follows—LML: designed the research, analyzed the data, wrote the manuscript, and had primary responsibility for the final content; BS-M, RJI, CAP, DLH, DL, and KL: designed the research; and all authors: interpreted the data, revised the manuscript, read and approved the final manuscript. None of the authors reported a conflict of interest related to the study.

REFERENCES

1. Hiza HA, Casavale KO, Guenther PM, Davis CA. Diet quality of Americans differs by age, sex, race/ethnicity, income, and education level. J Acad Nutr Diet 2013;113:297–306.
2. Banfield EC, Liu Y, Davis JS, Chang S, Frazier-Wood AC. Poor adherence to US dietary guidelines for children and adolescents in the National Health and Nutrition Examination Survey population. J Acad Nutr Diet 2016;116:21–7.
3. Nelson MC, Story M, Larson NI, Neumark-Sztainer D, Lytle LA. Emerging adulthood and college-aged youth: an overlooked age for weight-related behavior change. Obesity (Silver Spring) 2008;16: 2205–11.
4. Dunn JE, Liu K, Greenland P, Hilner JE, Jacobs DR. Seven-year tracking of dietary factors in young adults: the CARDIA study. Am J Prev Med 2000;18:38–45.
5. Murthy VL, Abbasi SA, Siddique J, Colangelo LA, Reis J, Venkatesh BA, Carr JJ, Terry JG, Camhi SM, Jerosch-Herold M, et al. Transitions in metabolic risk and long-term cardiovascular health: Coronary Artery Risk Development in Young Adults (CARDIA) study. J Am Heart Assoc 2016;5:e003934.
6. Liese AD, Krebs-Smith SM, Subar AF, George SM, Harmon BE, Neuhouser ML, Boushey CJ, Schap TE, Reedy J. The dietary patterns methods project: synthesis of findings across cohorts and relevance to dietary guidance. J Nutr 2015;145:393–402.
7. Harmon BE, Boushey CJ, Shvetsov YB, Ettienne R, Reedy J, Wilkens LR, Le Marchand L, Henderson BE, Kolonel LN. Associations of key diet-quality indexes with mortality in the Multiethnic Cohort: the Dietary Patterns Methods Project. Am J Clin Nutr 2015; 101:587–97.
8. Deshmukh-Taskar PR, Radcliffe JD, Liu Y, Nicklas TA. Do breakfast skipping and breakfast type affect energy intake, nutrient intake, nutrient adequacy, and diet quality in young adults? NHANES 1999-2002. J Am Coll Nutr 2010;29:407–18.
9. Fulkerson JA, Loth K, Bruening M, Berge J, Eisenberg ME, Neumark-Sztainer D. Time 2 tlk 2nite: use of electronic media by adolescents during family meals and associations with demographic characteristics, family characteristics, and foods served. J Acad Nutr Diet 2014;114: 1053–8.
10. Poti JM, Duffey KJ, Popkin BM. The association of fast food consumption with poor dietary outcomes and obesity among children: is it the fast food or the remainder of the diet? Am J Clin Nutr 2014;99: 162–71.
11. Sisson SB, Shay CM, Broyles ST, Leyva M. Television-viewing time and dietary quality among US children and adults. Am J Prev Med 2012;43:196–200.
12. Nader PR, Bradley RH, Houts RM, McRitchie SL, O'Brien M. Moderate-to-vigorous physical activity from ages 9 to 15 years. JAMA 2008;300:295–305.
13. Li K, Haynie D, Lipsky L, Iannotti RJ, Pratt C, Simons-Morton B. Changes in moderate-to-vigorous physical activity among older adolescents. Pediatrics 2016;138:e20161372.
14. Rideout VJ, Foehr UG, Roberts DF. Generation M2: media in the lives of 8- to 18-year-olds. Menlo Park (CA): The Kaiser Family Foundation; 2010.
15. Lenhart, A; Pew Research Center. Teen, social media and technology overview 2015. Washington (DC): Pew Research Center; 2015.
16. Larson NI, Neumark-Sztainer D, Hannan PJ, Story M. Trends in adolescent fruit and vegetable consumption, 1999–2004: project EAT. Am J Prev Med 2007;32:147–50.
17. Schmidt M, Affenito SG, Striegel-Moore R, Khoury PR, Barton B, Crawford P, Kronsberg S, Schreiber G, Obarzanek E, Daniels S. Fast-food intake and diet quality in black and white girls: the National Heart, Lung, and Blood Institute Growth and Health Study. Arch Pediatr Adolesc Med 2005;159:626–31.
18. Deshmukh-Taskar PR, Nicklas TA, O'Neil CE, Keast DR, Radcliffe JD, Cho S. The relationship of breakfast skipping and type of breakfast consumption with nutrient intake and weight status in children and adolescents: the National Health and Nutrition Examination Survey 1999-2006. J Am Diet Assoc 2010;110:869–78.
19. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol 2002;13:3–9.
20. Conway KP, Vullo GC, Nichter B, Wang J, Compton WM, Iannotti RJ, Simons-Morton B. Prevalence and patterns of polysubstance use in a nationally representative sample of 10th graders in the United States. J Adolesc Health 2013;52:716–23.
21. Kirkpatrick SI, Subar AF, Douglass D, Zimmerman TP, Thompson FE, Kahle LL, George SM, Dodd KW, Potischman N. Performance of the automated self-administered 24-hour recall relative to a measure of true intakes and to an interviewer-administered 24-h recall. Am J Clin Nutr 2014;100:233–40.
22. Thompson FE, Dixit-Joshi S, Potischman N, Dodd KW, Kirkpatrick SI, Kushi LH, Alexander GL, Coleman LA, Zimmerman TP, Sundaram ME, et al. Comparison of interviewer-administered and automated self-administered 24-hour dietary recalls in 3 diverse integrated health systems. Am J Epidemiol 2015;181:970–8.
23. Rhee JJ, Sampson L, Cho E, Hughes MD, Hu FB, Willett WC. Comparison of methods to account for implausible reporting of energy intake in epidemiologic studies. Am J Epidemiol 2015;181: 225–33.
24. Guenther PM, Casavale KO, Reedy J, Kirkpatrick SI, Hiza HA, Kuczynski KJ, Kahle LL, Krebs-Smith SM. Update of the healthy eating index: HEI-2010. J Acad Nutr Diet 2013;113:569–80.
25. Guenther PM, Kirkpatrick SI, Reedy J, Krebs-Smith SM, Buckman DW, Dodd KW, Casavale KO, Carroll RJ. The Healthy Eating Index-2010 is a valid and reliable measure of diet quality according to the 2010 dietary guidelines for Americans. J Nutr 2014;144:399–407.
26. Lipsky LM, Cheon K, Nansel TR, Albert PS. Candidate measures of whole plant food intake are related to biomarkers of nutrition and health in the US population (National Health and Nutrition Examination Survey 1999-2002). Nutr Res 2012;32:251–9.
27. Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of accelerometer cut points for predicting activity intensity in youth. Med Sci Sports Exerc 2011;43:1360–8.
28. ICPSR find and analyze data [Internet]. [cited 2016 Nov 21]. Available from: https://www.icpsr.umich.edu/icpsrweb/ICPSR/ssvd/series/195/variables.
29. Vereecken CA, Todd J, Roberts C, Mulvihill C, Maes L. Television viewing behaviour and associations with food habits in different countries. Public Health Nutr 2006;9:244–50.
30. Bobakova D, Hamrik Z, Badura P, Sigmundova D, Nalecz H, Kalman M. Test-retest reliability of selected physical activity and sedentary behaviour HBSC items in the Czech Republic, Slovakia and Poland. Int J Public Health 2015;60:59–67.
31. Currie C, Molcho M, Boyce W, Holstein B, Torsheim T, Richter M. Researching health inequalities in adolescents: the development of the Health Behaviour in School-Aged Children (HBSC) family affluence scale. Soc Sci Med 2008;66:1429–36.
32. Little RJ, Rubin DB. Statistical analysis with missing data. 2nd ed. Hoboken (NJ): John Wiley & Sons; 2002.
33. Buuren S, Groothuis-Oudshoorn K. MICE: multivariate imputation by chained equations in R. J Stat Softw 2011;45.
34. Raghunathan T, Solenberger P, Van Hoewyk J. IVEware: imputation and variance estimation software. Ann Arbor (MI): Survey Methodology Program, Survey Research Center, Institute for Social Research, University of Michigan; 2007.

35. Sijtsma FP, Meyer KA, Steffen LM, Shikany JM, Van Horn L, Harnack L, Kromhout D, Jacobs DR Jr. Longitudinal trends in diet and effects of sex, race, and education on dietary quality score change: the Coronary Artery Risk Development in Young Adults study. Am J Clin Nutr 2012;95:580–6.
36. Lien N, Lytle LA, Klepp K-I. Stability in consumption of fruit, vegetables, and sugary foods in a cohort from age 14 to age 21. Prev Med 2001;33:217–26.
37. Kant AK, Graubard BI. Race-ethnic, family income, and education differentials in nutritional and lipid biomarkers in US children and adolescents: NHANES 2003-2006. Am J Clin Nutr 2012;96:601–12.
38. Kirkpatrick SI, Dodd KW, Reedy J, Krebs-Smith SM. Income and race/ethnicity are associated with adherence to food-based dietary guidance among US adults and children. J Acad Nutr Diet 2012; 112:624–35.e6.
39. Marshall S, Burrows T, Collins CE. Systematic review of diet quality indices and their associations with health-related outcomes in children and adolescents. J Hum Nutr Diet 2014;27:577–98.
40. Larson NI, Neumark-Sztainer D, Hannan PJ, Story M. Family meals during adolescence are associated with higher diet quality and healthful meal patterns during young adulthood. J Am Diet Assoc 2007;107:1502–10.
41. Coon KA, Goldberg J, Rogers BL, Tucker KL. Relationships between use of television during meals and children's food consumption patterns. Pediatrics 2001;107:E7.
42. Lipsky LM, Iannotti RJ. Associations of television viewing with eating behaviors in the 2009 health behaviour in school-aged children study. Arch Pediatr Adolesc Med 2012;166:465–72.
43. Powell LM, Nguyen BT. Fast-food and full-service restaurant consumption among children and adolescents: effect on energy, beverage, and nutrient intake. JAMA Pediatr 2013;167:14–20.
44. Falbe J, Willett WC, Rosner B, Gortmaker SL, Sonneville KR, Field AE. Longitudinal relations of television, electronic games, and digital versatile discs with changes in diet in adolescents. Am J Clin Nutr 2014;100:1173–81.
45. Barr-Anderson DJ, Larson NI, Nelson MC, Neumark-Sztainer D, Story M. Does television viewing predict dietary intake five years later in high school students and young adults? Int J Behav Nutr Phys Act 2009;6:7.
46. Maier JH, Barry R. Associations among physical activity, diet, and obesity measures change during adolescence. J Nutr Metab 2015;2015: 805065.
47. Parsons TJ, Power C, Manor O. Longitudinal physical activity and diet patterns in the 1958 British Birth Cohort. Med Sci Sports Exerc 2006; 38:547–54.
48. Gebremariam MK, Bergh IH, Andersen LF, Ommundsen Y, Totland TH, Bjelland M, Grydeland M, Lien N. Are screen-based sedentary behaviors longitudinally associated with dietary behaviors and leisure-time physical activity in the transition into adolescence? Int J Behav Nutr Phys Act 2013;10:9.
49. Bellisle F, Dalix AM, Slama G. Non food-related environmental stimuli induce increased meal intake in healthy women: comparison of television viewing versus listening to a recorded story in laboratory settings. Appetite 2004;43:175–80.
50. Blass EM, Anderson DR, Kirkorian HL, Pempek TA, Price I, Koleini MF. On the road to obesity: television viewing increases intake of high-density foods. Physiol Behav 2006;88:597–604.
51. Boyland EJ, Halford JC. Television advertising and branding. Effects on eating behaviour and food preferences in children. Appetite 2013;62.
52. Leibowitz J, Rosch JT, Ramirez E, Brill J, Ohlhausen M. A review of food marketing to children and adolescents: a follow-up report. Washington (DC): Federal Trade Commission; 2012.