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Research Brief

Adolescent Diet Quality, Cardiometabolic Risk, and Adiposity: A Prospective Cohort

Kathy Hu[1,2]; Alyssa M. Button, PhD[1]; Claire M. Tate[1]; Chelsea L. Kracht, PhD[1]; Catherine M. Champagne, PhD, RDN[1]; Amanda E. Staiano, PhD[1]

ABSTRACT

Objective: Examine the prospective association among diet with adolescent cardiometabolic risk (CMR) and anthropometrics.

Methods: Secondary analysis of an observational study of adolescents aged 10−16 years. Twenty-four-hour food recalls were used to calculate Healthy Eating Index-2015 (HEI-2015) scores. Anthropometrics were assessed using magnetic resonance imaging, dual-energy x-ray absorptiometry, and height/weight measurements. CMR included mean arterial pressure, homeostatic model assessment for insulin resistance, high-density lipoprotein cholesterol, and triglycerides. Associations between HEI-2015 score at baseline with follow-up adiposity and CMR were examined using regression models.

Results: A total of 192 adolescents were included. Baseline HEI-2015 scores were inversely associated with follow-up total CMR z-score ($P = 0.01$), homeostatic model assessment for insulin resistance ($P < 0.01$), waist circumference z-score ($P = 0.02$), body mass index percentile ($P = 0.01$), fat mass ($P = 0.04$), lean mass ($P = 0.02$), and visceral adipose tissue mass ($P = 0.01$).

Conclusions and Implications: Adolescents with lower adherence to dietary guidelines and greater CMR and anthropometry measurements at baseline continued this trajectory across the observation.

Key Words: Nutrition, adiposity, cardiometabolic risk, HEI-2015, adolescents (*J Nutr Educ Behav.* 2023;55:851−860.)

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INTRODUCTION

Obesity in adolescence is associated with cardiometabolic risk (CMR) during adolescence and later hypertension, hyperglycemia, and dyslipidemia into adulthood.[1] A key association between obesity and CMR is dietary intake. Diets high in energy, fat, and refined carbohydrates and low in fruits, vegetables, and fiber are cross-sectionally associated with higher CMR factors and higher adiposity in adolescence.[2] Unfortunately, these poor dietary patterns are relatively reflective of the current US patterns among youth.[3] The diet quality of adolescents is among the worst across all age groups in the US,[4] preventing the risk of chronic disease through improving diet patterns is an area of great need.[5,6]

The Healthy Eating Index-2015 (HEI-2015) is a diet quality index used to measure alignment of diet with the 2015−2020 Dietary Guidelines for Americans.[7−9] These guidelines are the national recommendations co-authored by the US Department of Health and Human Services and the US Department of Agriculture and intended for use and dissemination by health professionals and policymakers for all individuals aged ≥ 2 years. Among adults in the US, research supports a link between diet quality as measured by HEI and CMR.[10−12] Several studies have examined the associations between diet quality and the risk of obesity, adiposity, and CMR in adolescents, but results thus far have been inconsistent and largely cross-sectional. Inverse associations between HEI-2010 and change in body mass index (BMI) in girls have been supported, but not among boys.[13] Total HEI-2015 and Alternative Healthy Eating Index-2010 scores were cross-sectionally inversely associated with the metabolic syndrome risk among a large sample of adolescents[14] and African American boys,[15] respectively. Overall, there is some research to support a connection between diet quality and adolescent weight, adiposity, and CMR factors. Current findings are inconsistent and rely on various measures of diet quality other than the current 2015−2020 Dietary Guidelines for Americans. Part of this inconsistency may be a reliance on measures of BMI instead of the more precise imaging estimates of body fat distribution and cardiometabolic risk factors, which are more precise ways to

[1]Pennington Biomedical Research Center, Louisiana State University, Baton Rouge, LA
[2]Episcopal School of Baton Rouge, Baton Rouge, LA

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Address for correspondence: Amanda E. Staiano, PhD, Pennington Biomedical Research Center, Louisiana State University, 6400 Perkins Rd, Baton Rouge, LA 70808; E-mail: amanda.staiano@pbrc.edu

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monitor adolescents' health still with clinical utility.

A dearth of prospective data among US adolescents examines the relationship among compliance with national dietary guidelines, CMR factors, and body composition. A prospective examination of diet quality may help identify targets for future interventions in families, homes, and communities. This study examined the association between diet quality at baseline with CMR factors and body composition 2-years later among adolescents.

METHODS

Participants

This study is a secondary analysis of the Translational Investigation of Growth and Everyday Routine in Kids cohort, a prospective observational study of adolescents aged 10−16 years recruited between 2016 and 2018 to examine combined associations between meeting physical activity, sleep, and overall dietary guidelines with CMR factors and adiposity (NCT02784509).[16] Recruitment took place using convenience sampling in metropolitan Louisiana, a medically underserved area characterized by high poverty levels, food insecurity, obesity, and related diseases.[17] Parent recruitment efforts included email listserv, community events, social media, and health fairs. Participants provided follow-up measures 2 years later (18−30 months), between 2018 and 2020, and were offered a total compensation of $100 for the completion of this study. Inclusion criteria for the study were having a body weight < 500 lbs and having the ability to understand instructions and complete all study procedures. Exclusion criteria were adolescent pregnancy, restrictive diet because of illness, or significant physical or mental disability that would impede walking, wearing an accelerometer or global positioning system monitoring, or responding to ecological momentary assessment. The study protocol and all procedures were approved through a full board review by the Pennington Biomedical Research Center Institutional Review Board. At baseline, parents provided written informed consent, and adolescents provided written informed assent.

Of the 342 eligible and enrolled adolescents, the final sample included 192 with complete baseline and follow-up data. There were no significant differences between the included and excluded adolescents in this study for age, sex, race, household income, puberty, in-school status, mean values of adiposity indicators, and CMR factor z-scores except for Homeostatic Model Assessment of Insulin Resistance (HOMA-IR; 0.15 vs −0.11, $P = 0.021$).

Procedures

Parents and adolescents attended an in-person orientation with study staff to orient to the study procedures, ask questions, and learn how to wear accelerometers and complete assessments accurately. At the baseline clinic visit, parents completed a demographic survey to provide reports of adolescent age, sex (male, female), race (American Indian/Alaska Native, Asian, Black/African American, Native Hawaiian or Other Pacific Islander, White) and ethnicity (Hispanic or Latino/a, non-Hispanic or Latino/a), household income (4 options to select income range), and if the adolescent was in a school term or on holiday. At both baseline and follow-up, adolescents were asked to wear an accelerometer for at least 7 days and to complete 2 24-hour dietary recalls for their food and drink intake before the appointment plus a 24-hour dietary recall during the appointment (for a total of at least 2−3 dietary recalls at both baseline and 2-year follow-up). As described below, anthropometrics, body composition, blood pressure, and clinical chemistry measurements were collected on the same day.

Measures

Diet quality. Twenty-four-hour food recall was assessed using the web-based Automated Self-Administered 24-hour Dietary Assessment Tool (ASA-24).[18] The ASA-24 has been validated in adolescents[19] and uses multiple prompts to elicit recall of food and beverages consumed the prior day.[20,21] Adolescents received instructions on completing the dietary recalls before the baseline visit. Adolescents were sent at unannounced intervals for 1 weekday and 1-weekend 24-hour recall before their baseline visit, which included a third dietary recall on a weekday. If 1 or no recalls were available after the baseline visit, adolescents were contacted within 30 days to complete additional recalls to capture the average intake of at least 2 recalls, as done similarly by the National Health and Nutrition Examination Survey (NHANES)[4] because of participant burden and the fact that the current study is examining the population and not any individual participant. These surveys were sent to the parent's email, and the parent was asked to have the adolescent respond and provide the adolescent with assistance as needed. Diet quality was calculated with the HEI-2015 score derived from the ASA-24 results and a SAS macro. The HEI-2015 was chosen for its alignment with the US Dietary Guidelines. The simple HEI scoring algorithm method created this score; all available recalls were averaged for each participant.[22] The total score of the HEI-2015 ranges from 0−100, with scores closer to 100 representing a higher quality of diet in alignment with the 2015−2020 Dietary Guidelines for Americans.[8,9] The HEI-2015 total score is derived from scoring 13 dietary components; maximum scores of 5 or 10 are possible for each component. HEI-2015 component scores of adequacy include total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids. HEI-2015 component scores of moderation are reverse-scored and include refined grains, sodium, added sugars, and saturated fats.

Weight. Trained research staff measured body weight to the nearest 0.1 kg using a Michelli GSE 460 scale (G.T. Michelli). Research staff measured participants wearing a gown and no shoes, then subtracted gown weight to calculate the final weight. Two measurements were averaged, or the closest 2 of 3, when measurements differed by more than 0.5 kg.

Standing height. Trained research staff measured standing height to the nearest 0.1 cm using a Harpenden stadiometer (Holtain Limited). Two measurements were averaged, or the closest 2 of 3, when measurements differed by > 0.5 cm.

Body mass index (percentile and z-score). BMI was measured using participant age, sex, height, and weight using the Centers for Disease Control and Prevention 2000 growth chart.[23] Participants were grouped into the following BMI categories: healthy weight or underweight (< 85th percentile), overweight (> 85th percentile to < 95th percentile), and obesity (> 95th percentile).

Waist circumference (WC). Participant WC was measured at the natural waist, between the inferior border of the rib cage and the superior aspect of the iliac crest, with clothing moved out of the way to the nearest 0.1 cm.[24]

Total fat and lean mass. Dual-energy x-ray absorptiometry (DXA) was used to measure total fat and lean mass (DXA) using a GE Lunar iDXA scanner (GE Medical Systems) and standard imaging and positioning protocol.[24] Body fat percentage was calculated as total fat mass divided by total mass (fat and lean mass).

Visceral adipose tissue (VAT). Water-fat shifting magnetic resonance imaging (MRI) was used to measure VAT from the highest point of the liver to the bottom of the right kidney using the General Electric Discovery 750 w 3.0 Tesla (GE Medical Systems). IDEAL-IQ imaging captured images during a single acquisition with a 20-second breath hold. A trained technician drew the visceral depot at each fifth slice, starting at 2 slices under the L4/L5 to the diaphragm. A validated algorithm was then used to calculate VAT and estimate total and subcutaneous fat in the abdomen. These procedures are described in greater detail elsewhere.[25]

Cardiometabolic risk. To measure cardiometabolic risk, a fasting blood sample was collected by a trained phlebotomist. High-density lipoprotein cholesterol (HDL-c) and triglycerides were obtained from a Trinity DXC600 manufactured by Beckman Coulter. Insulin and glucose were assayed on the Siemens Immulite 2000 and used to calculate HOMA-IR using the formula HOMA-IR = (insulin × glucose)/22.5.[26] High HOMA-IR increases insulin resistance, and vice versa for low HOMA-IR. Resting blood pressure was assessed using standard clinical procedures on a sphygmomanometer. Mean arterial pressure (MAP) was calculated as MAP = (SBP + 2 [DBP])/3.[27]

Physical activity. Actigraph GT3X+ accelerometers were used to measure physical activity for 7 continuous days (24 h/d). Moderate-to-vigorous physical activity was defined as meeting > 574 counts out of 15-second epochs of accelerometry data.[28] This was used as a covariate.

Adolescents responded to questions about pubertal development based on a series of standardized, validated drawings.[29] Adolescents self-reported using a scale of 1 (no development) to 5 (complete development) for female breasts or male genitalia and pubic hair. The pubertal stage was included as a covariate.

Statistical Analyses

A standardized cardiometabolic risk z-score was calculated on the basis of the sample and in accordance with accepted standards for pediatric practices based on their reflection of adult metabolic syndrome criteria[27]: BMI, MAP, fasting blood glucose, and triglycerides were regressed on the basis of age, sex, and race, and then the standardized residuals were summed (HDL-C), which is inversely related to cardiometabolic risk; thus, it is multiplied by −1. Paired t-tests were used to compare values from baseline to follow-up. Linear regression was used to assess associations of diet quality using baseline total HEI-2015 with each CMR and body composition outcome separately. For the general linear models, all analyses were first conducted after adjusting for baseline age and sex, race, household income, in-school status, puberty (also during follow-up), and moderate-to-vigorous physical activity, and then further baseline corresponding CMR and body composition. For the first series of models, differences in CMR factors and body composition based on different levels of total HEI-2015 (tertile 1: n = 64, range 23.8−41.7; tertile 2: n = 64, range 41.9−52.3; and tertile 3: n = 64, range 52.8−86.4 calculated from the sample) were tested using a general linear model. In addition, associations between changes in total HEI-2015 from baseline to follow-up and CMR and body composition were assessed using the general linear model. Sensitivity analyses were used to examine associations for specific HEI-2015 component scores and associations stratified by pubertal development groups at baseline and follow-up. All statistical analyses were performed using SPSS software (version 24.0, IBM, 2016).

RESULTS

A total of 192 participants with complete data collection from baseline to follow-up were included in the analyses from an initial sample of 342 participants at baseline. Those excluded included those missing data at baseline (7 missing DXA or MRI, 2 missing anthropometry, 21 did not complete dietary recalls, 3 did not complete blood draw) or those who did not return to follow-up (n = 84) or did not complete follow-up measures (8 missing DXA/MRI, 1 missing anthropometry, 18 missing dietary recalls, 6 did not complete blood draw; Figure 1). The mean time between baseline and follow-up measurements was 1.96 ± 0.22 years.

Table 1 describes the baseline and follow-up characteristics of the sample. At baseline, adolescents were aged 12.9 ± 1.9 years, 47.9% were male, 57.8% were White, and 33.3% were African American. Across the sample, 50.6% of adolescents were categorized as having healthy weight or underweight (n = 4) with a BMI percentile < 85th. There were no significant differences in the total HEI-2015 or any CMR factor between the baseline and the follow-up values. Body composition measurements, including BMI percentile, fat mass,

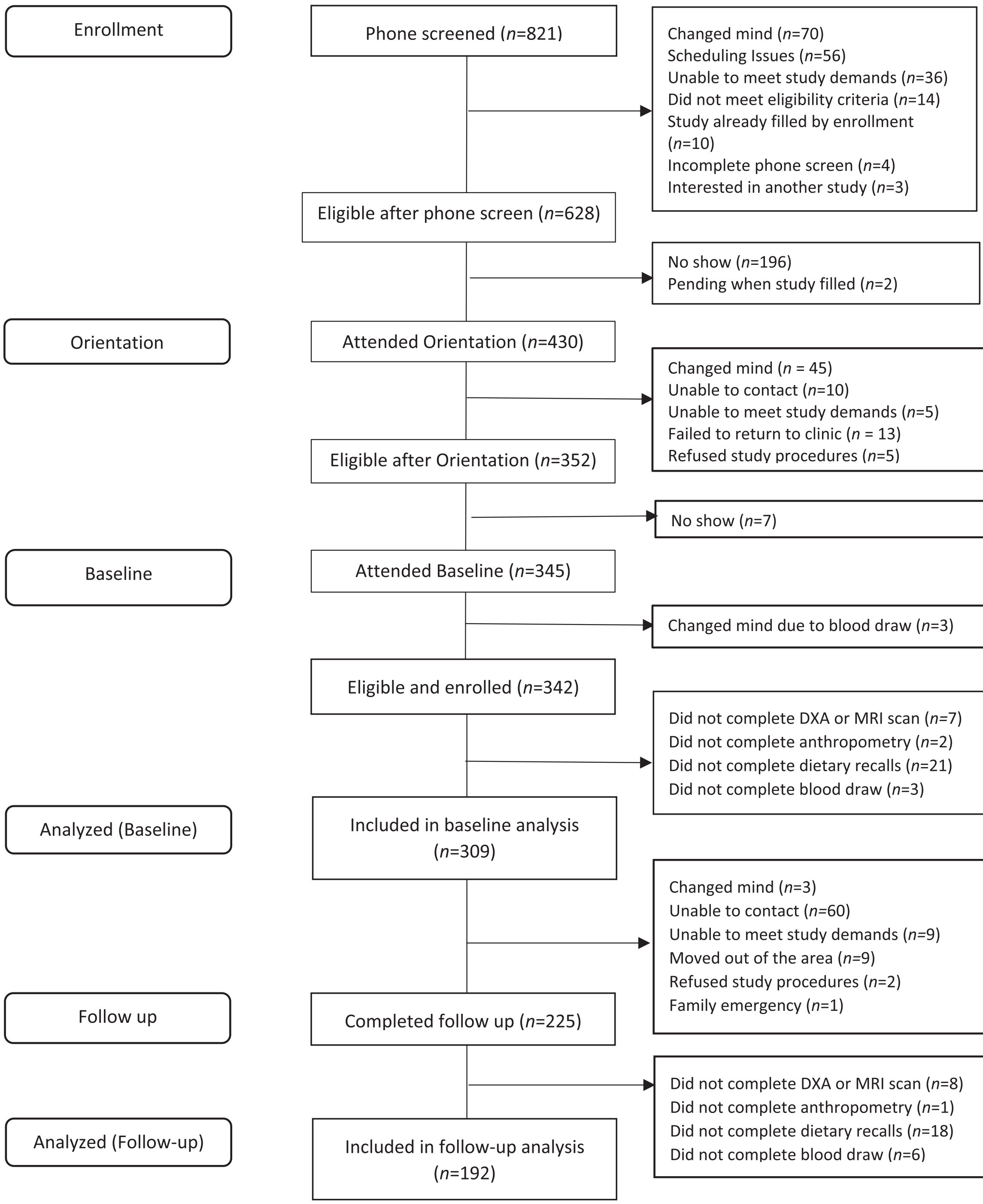

Figure 1. Consolidated Standards of Reporting Trials flow diagram of participants included in final analyses. DXA indicates dual-energy x-ray absorptiometry; MRI, Magnetic resonance imaging.

lean mass, and VAT mass, increased from baseline to follow-up, whereas body fat percentage decreased from baseline to follow-up (Table 1).

Total HEI-2015 scores of the current sample indicated adolescents met around 50% of the recommendations at baseline (47.6 ± 11.8) and follow-up (46.3 ± 11.5). HEI-2015 mean component scores are shown in Figure 2.

In multivariable-adjusted models (Table 2), baseline total HEI-2015 score was inversely associated with follow-up CMR z-score, HOMA-IR z-score, WC z-score, BMI percentile, fat mass, lean mass, and VAT mass. When controlling baseline values, associations were still significant for HOMA-IR z-score, WC z-score, BMI percentile, body fat, fat mass, and VAT mass.

The multivariable-adjusted follow-up means of CMR factors and adiposity across tertiles of baseline HEI-2015 scores are presented in Table 3, indicating an inverse association

Table 1. Demographic Characteristics, Total 2015 Healthy Eating Index (HEI-2015) Score, Body Composition and Cardiometabolic Risk Factors Among 192 Adolescents

Characteristic	Baseline (n = 192)	Follow-up (n = 192)	*P*[a]
Demographic			
Age (y)	12.9 ± 1.88	14.9 ± 1.91	
Male	92 (47.9)	–	
Race			
White	111 (57.8)	–	
African American	64 (33.3)	–	
Other[b]	17 (8.9)	–	
Annual household income			
< $29,999	19 (9.9)	–	
$30,000-69,999	45 (23.4)	–	
$70,000-139,999	67 (34.9)	–	
≥ $140,000	50 (26.0)	–	
Missing/refused	11 (5.7)	–	
In school (vs on school holiday)	139 (72.4)	116 (60.4)	
Puberty status			
Prepuberty	23 (12.0)	4 (2.1)	
In puberty	102 (53.1)	76 (39.6)	
Completed puberty	67 (34.9)	112 (58.3)	
Moderate-to-vigorous physical activity (min/d)	36.3 ± 21.0	25.5 ± 16.3	<0.001
Total HEI-2015 score[c]	47.6 ± 11.8	46.3 ± 11.5	0.21
Body composition			
Body mass index percentile	71.3 ± 30.2	73.4 ± 28.4	0.028
Body fat (%)	34.6 ± 10.3	33.8 ± 11.2	0.035
Fat mass (kg)	21.9 ± 14.4	25.3 ± 17.0	<0.001
Lean mass (kg)	36.8 ± 10.4	43.8 ± 10.6	<0.001
Visceral adipose tissue mass (kg)	0.55 ± 0.47	0.63 ± 0.55	<0.001
Cardiometabolic risk factors[d]			
High-density lipoprotein cholesterol z-score	0.02 ± 0.98	0.05 ± 0.97	0.39
HOMA-IR z-score	−0.11 ± 0.83	−0.07 ± 0.85	0.55
Mean arterial pressure z-score	−0.08 ± 1.02	0.002 ± 1.02	0.23
Triglycerides z-score	−0.04 ± 1.05	−0.004 ± 1.06	0.68
Waist circumference z-score	−0.03 ± 1.01	−0.04 ± 0.93	0.82
Total cardiometabolic risk factors z-score	−0.26 ± 3.20	−0.07 ± 3.31	<0.001

HOMA-IR indicates Homeostatic Model Assessment for Insulin Resistance.
[a]Paired t-tests were used to compare values from baseline to follow-up; [b]Participants marked "Other" when asked to report race given the following options: American Indian/Alaska Native, Asian, Native Hawaiian, or Other Pacific Islander; [c]The total HEI-2015 score is derived from scoring 13 dietary components, and maximum scores of 5 and 10 are possible for each component; [d]A standardized cardiometabolic risk z-score was calculated with 5 individual cardiometabolic risk components (high-density lipoprotein cholesterol, Homeostatic Model Assessment for Insulin Resistance, mean arterial pressure, triglycerides, and waist circumference) in accordance with accepted standards for pediatric practices.[30]
Significance was defined as $P < 0.05$.
Note: Values are presented as mean ± SD or n (%).

between baseline total HEI-2015 score and follow-up BMI percentile, VAT mass, HOMA-IR z-score, WC z-score, and total CMR z-score. However, after additional adjustment for baseline CMR factors and body composition, these associations became no longer significant except for BMI percentile and VAT mass.

Sensitivity Analysis

In multivariable-adjusted models, the HEI-2015 component scores for greens and beans were inversely associated with total CMR factors ($\beta = -0.273$, $P = 0.03$), HOMA-IR z-score ($\beta = -0.088$, $P = 0.01$), and BMI percentile ($\beta = -2.637$, $P = 0.02$). Seafood and plant proteins were also inversely associated with total CMR factors ($\beta = -0.237$, $P = 0.03$), HOMA-IR z-score ($\beta = -0.076$, $P = 0.01$), triglycerides z-score ($\beta = -0.085$, $P = 0.02$), BMI percentile ($\beta = -1.939$, $P = 0.04$), and lean mass ($\beta = -0.626$, $P = 0.05$). HEI-2015 component score for whole fruit was inversely associated with WC z-score ($\beta = -0.086$, $P = 0.01$), BMI percentile ($\beta = -2.766$, $P = 0.01$), fat mass ($\beta = -1.409$, $P = 0.01$), and lean mass ($\beta = -0.914$, $P = 0.01$).

When stratified by puberty development, the inverse association was still significant among participants who remained in the completed puberty stage at baseline and follow-up for fat mass ($\beta = -0.444$, $P = 0.05$), HOMA-IR z-score ($\beta = -0.023$, $P = 0.03$), triglycerides z-score ($\beta = -0.022$, $P = 0.01$), and total cardiometabolic risk z-score ($\beta = -0.09$, $P = 0.01$) and

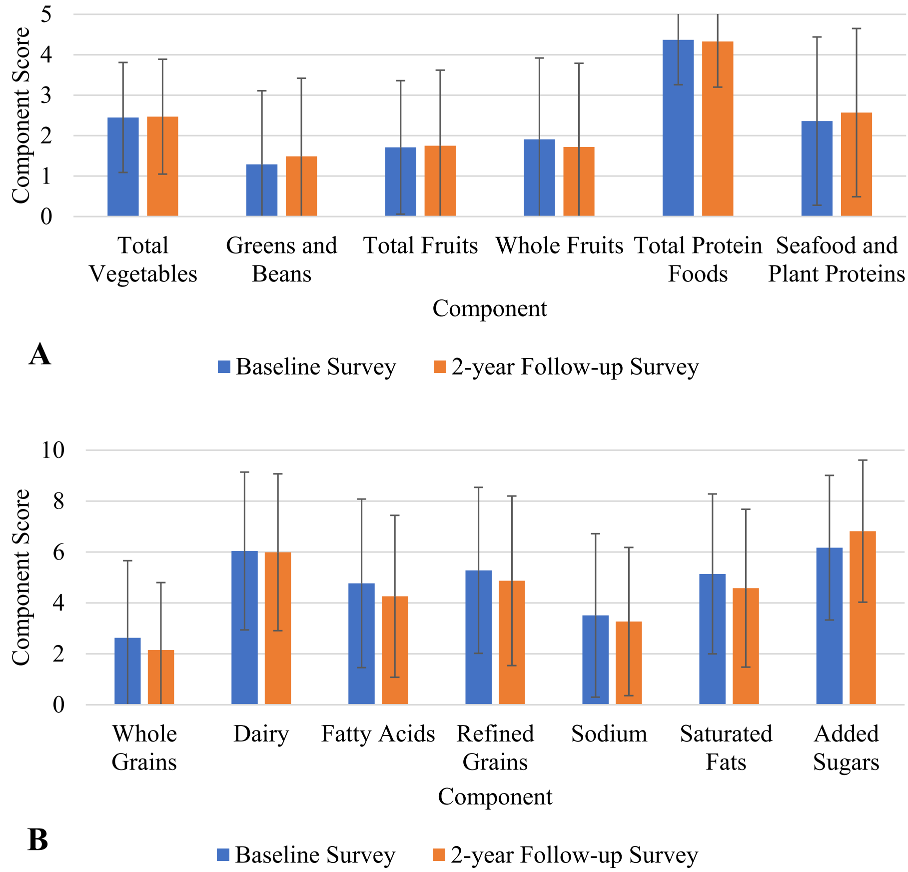

Figure 2. Healthy Eating Index-2015 (HEI-2015) mean scores and SD[a] scored out of 5 (A) and 10 (B). [a]Panel A components have a maximum score of 5, and Panel B components have a maximum score of 10. Higher scores indicate greater conformance with the 2015−2020 Dietary Guidelines for Americans. HEI-2015 component scores of moderation are reverse-scored and include refined grains, sodium, added sugars, and saturated fats.

was borderline significant for HOMA-IR z-score (P = 0.07), WC z-score (P = 0.08), and total CMR z-score (P = 0.07); and among participants who went from the prepuberty stage at baseline to the in-puberty stage at follow-up for body fat (β = −0.35, P = 0.02) and VAT mass (β = −0.013, P = 0.03). The inverse association was also borderline significant among participants in the prepuberty stage at baseline and follow-up for BMI percentile (β = −0.53, P = 0.08) and fat mass (β = −0.241, P = 0.08). Analyses among participants who remained in the prepuberty stage at baseline and follow-up yielded no significant associations.

DISCUSSION

This study examined the relationships among adolescent adherence to the 2015−2020 Dietary Guidelines for Americans and measures of CMR factors and adiposity. These findings indicated baseline HEI-2015 scores were inversely associated with CMR z-score, HOMA-IR z-score, WC z-score, BMI percentile, fat mass, lean mass, and VAT mass among adolescents at a 2-year follow-up. However, when the baseline value of the dependent variable was included as a covariate, associations were attenuated to nonsignificant except for BMI percentile and VAT mass. In other words, the adolescent's baseline adiposity or CMR z-score was a more powerful predictor of their cardiometabolic profile than their dietary intake, suggesting the adverse effects of a poor diet had already established a trajectory of adiposity and health risk in these adolescents.

The overall mean HEI-2015 score in this present study was 47.6 at baseline and 46.3 during follow-up, which is similar but slightly worse than the average HEI-2015 score for US adolescents aged 9−13 years (n = 53) and aged 14−18 years (n = 49) based on the nationally representative adolescents surveyed in the National Health and Nutrition Examination Survey (NHANES) 2017−2018.[4] Diet quality is a major factor associated with obesity[2]; thus, the low overall score in this sample may contribute to the higher prevalence of obesity in Louisiana as compared with the larger US population.[30]

Considering overall eating patterns, these findings showed that adolescents with poor adherence to the 2015−2020 Dietary Guidelines for Americans and associated CMR factors continued this same trajectory over 2 years. Trends in US youth eating patterns have shown modest improvements between 1999 and 2016, with more youth moving from poor-quality diets to intermediate quality diets,[31] which tracks with slowing, but not yet receding, youth

Table 2. Baseline Total Healthy Eating Index-2015 and Follow-up Body Composition and Cardiometabolic Risk Factors[a]

	Baseline Total Healthy Eating Index-2015 Score			
Variables	**Multivariable-adjusted β**	***P***	**Multivariable-adjusted β**	***P***
Body composition during follow-up				
Body mass index percentile	−0.428[c]	0.010	−0.164[d]	0.036
Body fat (%)	−0.110[b]	0.066	−0.063[d]	0.040
Fat mass (kg)	−0.191[b]	0.046	−0.090[d]	0.016
Lean mass (kg)	−0.136[b]	0.014	−0.035[d]	0.162
Visceral adipose tissue mass (kg)	−0.008[b]	0.015	−0.004[d]	0.009
Cardiometabolic risk factors during follow-up				
High-density lipoprotein cholesterol Z-score	−0.004[c]	0.499	−0.002[e]	0.685
Homeostatic Model Assessment for Insulin Resistance Z-score	−0.016[c]	0.002	−0.009[e]	0.038
Mean arterial pressure z-score	−0.012[c]	0.059	−0.008[e]	0.135
Triglycerides z-score	−0.007[c]	0.296	−0.003[e]	0.594
Waist circumference z-score	−0.014[c]	0.012	−0.005[e]	0.015
Total cardiometabolic risk factors z-score	−0.052[c]	0.008	−0.022[e]	0.120

[a]Associations between baseline total Healthy Eating Index-2015 and follow-up body composition and cardiometabolic risk factors were determined using Linear Regression; [b]Multivariable adjusted for baseline age, sex, household income, in-school status, puberty (during follow-up also), and moderate-to-vigorous physical activity; [c]Multivariable adjusted for baseline household income, in-school status, puberty (during follow-up also), and moderate-to-vigorous physical activity; [d]Multivariable adjusted for baseline age, sex, household income, in-school status, puberty (during follow-up also), moderate-to-vigorous physical activity, and baseline corresponding cardiometabolic risk factors and body composition; [e]Multivariable adjusted for baseline household income, in-school status, puberty (during follow-up also), moderate-to-vigorous physical activity, and baseline corresponding cardiometabolic risk factors and body composition.
Significance was defined as $P < 0.05$.

obesity prevalence in the US.[32] Liu et al[31] suggest these improvements may be attributed to a shift toward focusing on healthy diet patterns, initiatives for increasing physical activity, strengthening child nutrition programs, and more rigorous standards for school meals throughout this period (1999−2016). Compared with full-service and quick-service options, adolescents are more likely to receive meals aligned with the 2015−2020 Dietary Guidelines for Americans at school or when purchasing food from stores.[33]

The results found HEI-2015 component scores of greens and beans, seafood and plant proteins, whole fruit, and whole grains to be inversely related to CMR factors and body composition and refined grain component scores to be positively related. It appears that participants within this sample are not consuming enough of the adequacy components compared with the moderation components. Current US Department of Agriculture Food and Nutrition Service requirements under the *National School Lunch Program* focus on including fruits, vegetables, grains (80% whole grain-rich), meats/meat alternates, and fluid milk.[34] Based on present findings, to protect against CMR and increased body composition, guidelines, and policies may consider increasing seafood and plant proteins. Additional research examining the associations between dietary patterns using alternative scoring procedures and guidelines and prospective anthropometric and cardiometabolic risk in adolescents may provide insight into additional options for health-promoting intake.

HEI-2015 added sugar component scores were not significantly associated with anthropometric or cardiometabolic outcomes. The HEI-2015 version, compared with the HEI-2010 version, divided the previous scale of empty calories into added sugars and saturated fat scales, recognizing differences in how carbohydrates and lipids are digested and metabolized.[7] This finding is interesting as added sugar intake is often reported in the media as a target to improve childhood rates of obesity,[35] although research fails to support the contribution of sugar intake above and beyond matched macronutrient distributed groups.[36] The results of this study suggest that patterns of intake, vs sugar intake specifically, contribute to associations with anthropometric and cardiometabolic outcomes.

Puberty is also a considerable risk factor associated with CMR factors and body composition.[37−40] Our study indicated that the inverse association between baseline total HEI-2015 and select CMR factors and body composition was present for participants who went from the prepuberty to in-puberty stages, in-puberty to completed puberty stages, and remained in the completed puberty stages from baseline to follow-up. Adolescence is critical to provide nutritional intervention to promote positive prospective anthropometric and cardiometabolic associated outcomes.

This study has several strengths. First, the longitudinal study design allowed an assessment of baseline and 2-year follow-up changes in diet quality in association with CMR factors and adiposity. Second, body composition components were measured repeatedly with MRI and DXA.

Table 3. Adjusted Means of Follow-up Body Composition and Cardiometabolic Risk Factors According to Different Levels of Baseline Total Healthy Eating Index 2015 (HEI-2015) Score[a]

	Baseline Total HEI-2015 Score			
Variables	**Tertile 1**	**Tertile 2**	**Tertile 3**	***P* for trend**
No. of participants	64	64	64	
Baseline total HEL-2015 score (range)	23.8–41.7	41.9–52.3	52.8–86.4	
Multivariable-adjusted				
Body composition during follow-up				
Body mass index percentile[c]	79.7 ± 3.32	73.9 ± 3.31	66.7 ± 3.32	0.02
Body fat (%)[b]	35.3 ± 1.20	33.9 ± 1.20	32.3 ± 1.21	0.20
Fat mass (kg)[b]	28.2 ± 1.92	25.8 ± 1.92	21.9 ± 1.92	0.07
Lean mass (kg)[b]	45.8 ± 1.11	44.2 ± 1.11	41.4 ± 1.11	0.02
Visceral adipose tissue mass (kg)[b]	0.78 ± 0.06	0.61 ± 0.06	0.50 ± 0.06	0.01
Cardiometabolic risk factors during follow-up [c]				
High-density lipoprotein cholesterol Z-score	0.17 ± 0.12	−0.07 ± 0.12	0.03 ± 0.12	0.37
HOMA-IR z-score	0.13 ± 0.10	−0.08 ± 0.10	−0.27 ± 0.10	0.03
Mean arterial pressure z-score	0.13 ± 0.13	0.12 ± 0.12	−0.24 ± 0.12	0.06
Triglycerides z-score	0.15 ± 0.13	−0.15 ± 0.13	−0.01 ± 0.13	0.30
Waist circumference z-score	0.14 ± 0.11	0.02 ± 0.11	−0.28 ± 0.11	0.02
Total cardiometabolic risk factors z-score	0.71 ± 0.40	−0.15 ± 0.39	−0.77 ± 0.39	0.03
Multivariable-adjusted				
Body composition during follow-up				
Body mass index percentile[e]	74.8 ± 1.57	75.4 ± 1.55	70.1 ± 1.56	0.04
Body fat (%)[d]	34.6 ± 0.61	34.2 ± 0.61	32.7 ± 0.61	0.07
Fat mass (kg)[d]	26.6 ± 0.75	25.2 ± 0.74	24.0 ± 0.75	0.05
Lean mass (kg)[d]	44.4 ± 0.50	43.5 ± 0.50	43.6 ± 0.51	0.41
Visceral adipose tissue mass (kg)[d]	0.69 ± 0.03	0.63 ± 0.03	0.57 ± 0.03	0.01
Cardiometabolic risk factors during follow-up				
High-density lipoprotein cholesterol z-score[e]	0.16 ± 0.08	−0.09 ± 0.08	0.07 ± 0.08	0.11
HOMA-IR z-score[e]	0.05 ± 0.09	−0.11 ± 0.09	−0.16 ± 0.09	0.22
Mean arterial pressure z-score[e]	0.09 ± 0.11	0.07 ± 0.11	−0.16 ± 0.11	0.20
Triglycerides z-score[e]	0.11 ± 0.12	−0.15 ± 0.12	0.03 ± 0.12	0.31
Waist circumference z-score[e]	0.04 ± 0.04	−0.06 ± 0.04	−0.11 ± 0.04	0.06
Total cardiometabolic risk factors z-score[e]	0.40 ± 0.28	−0.35 ± 0.28	−0.26 ± 0.28	0.13

HOMA-IR indicates Homeostatic Model Assessment for Insulin Resistance.
[a]Associations between baseline tertiles of the total 2015 Healthy Eating Index and follow-up body composition and cardiometabolic risk factors were determined using a general linear model; [b]Multivariable adjusted for baseline age, sex, household income, in-school status, puberty (also during follow-up), and moderate-to-vigorous physical activity; [c]Multivariable adjusted for baseline household income, in-school status, puberty (also during follow-up), and moderate-to-vigorous physical activity; [d]Multivariable adjusted for baseline age, sex, household income, in-school status, puberty (also during follow-up), moderate-to-vigorous physical activity, and baseline corresponding cardiometabolic risk factors and body composition; [e]Multivariable adjusted for baseline household income, in-school status, puberty (during follow-up also), moderate-to-vigorous physical activity, and baseline corresponding cardiometabolic risk factors and body composition.
Significance was defined as $P < 0.05$.
Note: Values are presented as mean ± SE.

These methods are more precise measures of adiposity than traditional BMI measurements and are the gold standard of research.[25,41] Third, using the HEI-2015 score to examine diet quality can be put into context by following the national dietary guidelines and comparing them with other samples or populations. Limitations of this study must also be recognized. First, the sample was recruited from a metropolitan area in Louisiana in which the prevalence of adolescent obesity is higher than the national average.[30] Thus, these findings may have a ceiling effect and be relevant to this particular population and/or those populations at greater risk. Moreover, adolescents were recruited using convenience sampling, which may introduce sampling or selection bias. Second, the accuracy of diet recalls is subject to social, economic, and cultural bias. Third, though the data analyses adjusted for some confounding factors, significant factors, such as maternal prepregnancy BMI and genetic factors, were not measured and could not be evaluated. These factors may be relevant for future research examining similar relationships and outcomes.[42,43]

IMPLICATIONS FOR RESEARCH AND PRACTICE

Adolescent diet patterns fall far from meeting national dietary guidelines. This study demonstrated static patterns of insufficient diet quality among adolescents over 2 years. Those who started at baseline with poorer diet quality had greater overall CMR and anthropometric measurements at follow-up among a sample of adolescents from Louisiana. These findings provide a novel understanding of the prospective relationships among adolescent diet quality, CMR factors, and body composition. Examining these clinical health risk markers in addition to anthropometry is important. This study found specific diet quality patterns associated with adolescent CMR factors and highlighted these findings for suggested guidance on dietary pattern recommendations and requirements. Promotion of nutrition knowledge is necessary, but knowledge does not equal adherence.[44] Nutrition knowledge is not consistently linked with food consumption behaviors[45]; thus, identifying barriers to consuming a healthful diet and investigating effective strategies to overcome these barriers in adolescence may curtail future overall CMR and adiposity. Effective and timely intervention focusing on adherence to dietary guidelines is necessary for improving diet quality and reducing overall CMR and adiposity in this age range.

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ORCIDs

Claire M. Tate: http://orcid.org/0000-0003-1640-4838
Chelsea L. Kracht: http://orcid.org/0000-0002-5467-0849
Catherine M. Champagne: http://orcid.org/0000-0001-6127-1072
Amanda E. Staiano: http://orcid.org/0000-0001-7846-046X