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Association between Meeting Physical Activity, Sleep, and Dietary Guidelines and Cardiometabolic Risk Factors and Adiposity in Adolescents

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Abstract

PURPOSE: To assess the associations of meeting physical activity (PA), sleep, and dietary guidelines with cardiometabolic risk factors and adiposity in adolescents.

METHODS: The sample included adolescents aged 10–16 y. Accelerometry was used to measure PA and sleep over 7 days, 24 hours/day. The PA guideline was defined as ≥60 min/day of moderate-to-vigorous PA. The sleep guideline was 9–11 hours (10–13 y) or 8–10 hours (14–16 y) per night. The dietary guideline was based on the Healthy Eating Index calculated from dietary recalls. Cardiometabolic risk factors and adiposity were assessed in an in-patient setting. Linear regression was used to examine the association between meeting each guideline and cardiometabolic risk factors/adiposity, adjusted for confounders and meeting other guidelines.

RESULTS: Of the 342 participants, 251 (73%) provided complete measurements. Adolescents were 12.5±1.9 y [African-American (37%) and White (57%), girls (54%), and overweight or obesity (48%)]. Half met the sleep guideline (52%), few met the PA guideline (11%), and the top quintile was pre-selected as meeting the diet guideline (20%). Most met one (47%) or no guidelines (35%), and few met multiple guidelines (18%). Meeting the PA guideline was associated with lower cardiometabolic risk factors and adiposity ($p<0.05$ for all). Compared to meeting no guidelines, those who met multiple guidelines had lower cardiometabolic risk factors and adiposity ($p<0.05$ for all).

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IMPLICATIONS AND CONTRIBUTIONS
In this sample, few adolescents had adequate physical activity or diet, but about half had adequate sleep. Having adequate amounts of multiple behaviors was related to better cardiometabolic health and less excess weight. Attention to improving multiple behaviors (physical activity, sleep, and diet) may provide the most benefit in adolescence.

COMPETING INTERESTS:
The authors declare that they have no competing interests.

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CONCLUSIONS: Few met the PA or multiple guidelines, and not meeting guidelines was associated with adverse cardiometabolic factors and adiposity. Multidisciplinary strategies for improving multiple behaviors are needed to improve adolescent health.

Keywords

exercise; public health; nutrition

INTRODUCTION

Adolescence is an important time in the life course. Many positive behaviors contribute to adolescent health, including adequate physical activity,[1] adequate sleep,[2] and proper dietary intake.[3] Unhealthy behaviors may compromise healthy development during this period, related to excess weight gain[4] and poor metabolic health.[5] Excess weight gain can translate into obesity, and adolescents with obesity are five times more likely to have obesity in adulthood.[6] Identification of adolescent health behaviors that contribute to excess weight gain is essential for the promotion of healthy development.

National guidelines exist for physical activity, sleep, and diet to promote adequate health and guide health practitioners. The *Physical Activity Guidelines for Americans, 2nd Edition* recommends that adolescents obtain ≥60 minutes per day of moderate-to-vigorous physical activity (MVPA),[7] and the National Sleep Foundation has age specific guidelines for sleep duration for adolescents (9–11 hours per night for ages 10 to13 years and 8–10 hours per night for ages 14 to 17 years).[8] The *2015 Dietary Guidelines for Americans* focuses on dietary quality[9] including 13 components of a healthy diet related to adequacy and moderation of intake. Evaluated separately, meeting each behavior's respective guidelines has been associated with lower cardiometabolic risk[10,11] and adiposity in adolescents.[12]

Physical activity, sleep, and diet are likely interrelated,[13] hypothesized mainly through timing of behaviors. For diet and sleep, it is hypothesized that those who consume unhealthy food at night may delay sleep onset, thus shortening sleep duration.[14] Short sleep may relate to skipping meals, including breakfast,[15] and skipping breakfast is related to poor diet quality.[16] Physical activity and sleep are related, as earlier wake times are associated with more MVPA compared to later wake times.[17] Further, adolescents who participate in organized sports report lower intake of unhealthy foods and fewer irregular meals compared to those who do not participate in organized sports.[18] All three behaviors may be influenced by in-school status and whether or not the adolescent has structured days.[19] Together, one behavior may influence adequate amounts of the other two behaviors. Despite these potential relationships, there is limited assessment of the association between meeting multiple guidelines and adolescent health. Assessing these behaviors together in a collective manner provides additional understanding to the development of cardiometabolic risk and adiposity in this age range. Therefore, the purpose of this study is to investigate the collective influence of meeting the physical activity, sleep, and dietary guidelines on cardiometabolic risk factors and adiposity in adolescents.

METHODS

Participants

Adolescents aged 10 to 16 years were recruited between August 2016 and August 2018 from a southeastern state in the U.S. to participate in a prospective observational cohort study. The present analysis used baseline measurements. Parents of adolescents were recruited through convenience sampling, such as email list serves, health fairs, schools, and social media campaigns. Exclusion criteria for adolescents were pregnancy, body weight exceeding 500 pounds, a medically restrictive diet, and significant physical or mental disabilities that would hinder walking or wearing an accelerometer. Pennington Biomedical Research Center's Institutional Review Board approved the study (IRB #2016–028).

Procedures

After obtaining written informed consent of the parent/guardian and written assent of the adolescent, the adolescent was given an accelerometer to wear on their hip for seven days. During this seven-day period, the adolescent was asked to complete two online dietary recalls. After the seven-day period, the adolescent returned for a clinical visit and asked to fast for 12 hours before their visit. The visit included anthropometric measurements, questionnaires, another dietary recall, and assessment of cardiometabolic risk factors. Parents completed a demographic form that included the adolescent's date of birth, sex, and race/ethnicity. Adolescents reported whether they were in or out of school at the time of the measurement. Adolescents reported their stage of sexual maturation based on a set of standardized validated drawings that displayed progressive pubertal stages from incomplete development to complete development for specific parts of the male or female body.[20] Demographic and study questionnaires were conducted and managed using Research Electronic Data Capture (REDCap), an electronic data capture tool hosted by Pennington Biomedical Research Center. REDCap is a secure, web-based application design to support data capture specific for research studies.[21]

Physical Activity

Adolescents wore an ActiGraph GT3X+ accelerometer (Pensacola, FL) on their hip for 24-hours/day over 7 days. The accelerometer recorded in 15-second epochs. A previously published algorithm differentiated between sleep time and non-wear time.[22,23] The present analysis included adolescents who had at least four days (including one weekend day) with 10 hours of wear time (not including non-wear or sleep) based on published guidelines.[24] MVPA was classified using validated cut points for this age range, which was >574 counts/15 seconds.[25] The physical activity guideline for this age range is ≥60 minutes per day of MVPA.[7] Adolescents who averaged ≥60 minutes of daily MVPA across available days were classified as meeting the physical activity guideline.

Sleep Time

Sleep time was calculated using total sleep episode time, which is the amount of time between estimated bed and wake times determined via the accelerometer. Sleep time was averaged over the number of complete days from an algorithm determined standard (at least

160 minutes of sleep), and adolescents who contributed at least three days (including one weekend) of complete sleep were included in the analysis based on the published algorithm.[22,23] The National Sleep Foundation guidelines are 9–11 hours for 10 to 13 years of age and 8–10 hours for 14 to 16 years of age.[8] Adolescents whose average nightly sleep duration was within their age-specific guideline were classified as meeting the sleep guideline.

Dietary Intake

Adolescents were asked to complete three dietary recalls, including two recalls at home and one at the clinic visit. The dietary recalls were completed using the Automated Self-Administered 24-Hour Dietary Assessment Tool (ASA-24 2016), a web-based program that administers 24-hour dietary recalls and developed by the National Cancer Institute.[26] The ASA-24 uses the Automated Multiple Pass Method to provide multiple prompts for recall of both food and beverages throughout the prior day and has been validated within this age range.[27] Adolescents received instructions for completing the dietary recalls prior to the baseline visit. The two dietary recalls were sent at preselected intervals that were unannounced so the adolescents could complete at least one weekday and one weekend recall before the baseline visit. Adolescents were asked to complete a third dietary recall at the in-clinic baseline visit, which occurred on a weekday. If only one or no dietary recalls were available after the baseline visit, the adolescent was contacted within 30 days to complete additional recalls to capture their average intake. Dietary quality was measured by the Healthy Eating Index (HEI) 2015, which is a calorie-adjusted score based on 13 components of the 2015 Dietary Guidelines for Americans.[9] HEI total score (HEI score) is the sum of the 13 components, with components ranging from 5–10 points and a total score ranging from 0–100, with a higher score indicating healthier dietary quality. Similar to another study evaluating dietary quality,[28] the top quintile (20%) of sample scores was deemed as meeting the dietary guideline. In the analytic sample, the top quintile had a HEI score above 63.0, and these adolescents were classified as meeting the dietary guideline. Adolescents who completed at least one dietary recall were included in analysis.

Cardiometabolic Risk Factors

A fasting blood sample was drawn using venipuncture. The blood sample was used to measure high-density lipoprotein (HDL-C), triglycerides, glucose, and insulin. HDL-C was assayed via a Trinity DXC600. A Beckman Coulter obtained serum triglyceride and glucose, and an immunoassay on a Siemens Immulite 2000 determined insulin level.[29] A sphygmomanometer measured resting blood pressure, using the average of two systolic (SBP) and diastolic (DBP) measurements. Trained research staff measured waist circumference in duplicate at the natural waist, mid-point between the rib cage's inferior border and the superior aspect of the iliac crest with clothing moved out of the way. A third measure occurred if the measurements differed by more than 0.5 cm.

Individual component and total risk scores were standardized since cardiometabolic risk differs by age, sex, race, and puberty status. Individual components included waist circumference, mean arterial pressure (MAP = ((2*DBP)+SBP)/3), HDL-C, triglycerides, and homeostasis assessment model of insulin resistance (HOMA-IR = (insulin (uU/ml)*glucose (mg/dL))/405). These measures were regressed onto demographic variables (age, sex, race, and puberty status) and standardized.[30] The standardized residuals were calculated for each individual component, the HDL-C score was multiplied by −1 since it is inversely related to risk, and all standardized residuals were summed for a continuous cardiometabolic risk factor score based on previous methodology.[30]

Adiposity

A research staff member measured height and weight with participant's wearing a gown and no shoes twice to the nearest 0.1 cm and 0.1 kg, respectively, then subtracted gown weight to calculate final weight. A third measurement followed if the two measurements differed by more than 0.5 units. Age and sex adjusted body mass index (BMI) percentiles were calculated based on a national reference.[31] A whole-body DXA scan using a GE iDXA scanner (GE Medical Systems, Milwaukee, WI) assessed body fat. The amount of body fat relative to the total body weight determined total body fat percentage. General Electric Signal Excite (3.0 Tesla; GE Medical Systems, Waukesha, WI) scanner performed abdominal MRI scans. A series of scans from the highest point of the liver to the bottom pole of the right kidney were acquired, and the Analyze (CNSoftware, Rochester, MN) software package analyzed the slice images. One trained technician manually drew visceral adipose tissue (VAT) area, and additional calculations determined VAT volume (liters).[29]

Data Analysis

Central tendencies of descriptive characteristics were calculated. Linear models were used to examine the associations among individual behaviors, individual guidelines, and number of guidelines with the dependent variables of cardiometabolic risk factors and adiposity. All models were adjusted for age, sex, race, and in-school status. The associations between physical activity (MVPA minutes), sleep (minutes), and dietary quality (HEI score) and cardiometabolic risk factors or adiposity were examined with adjustment for the other two behaviors not serving as the independent variable (e.g. when sleep was the independent variable, then physical activity and diet were covariates). Models examining the association between meeting individual guidelines (physical activity, sleep, and diet) and the dependent variables (cardiometabolic risk factors and adiposity) were adjusted for the same covariates and meeting the other two guidelines also. Number of guidelines met was the sum of physical activity, sleep, and diet guidelines achieved (possible score 0–3). The association of guidelines met was examined by comparing meeting one or 2+ guidelines to zero guidelines (referent). A sensitivity analysis was completed with adolescents who completed all three days of dietary intake to assess ideal compliance. All statistical analysis was conducted using SAS 9.4 (Cary, N.C.).

RESULTS

Of the 342 participants, 251 provided complete measures. Of the 91 who did not provide complete measures, 26 did not have a complete dietary recall due to technical issues, 33 did not wear the accelerometer or had inadequate wear time, 15 had insufficient sleep wear time, 8 did not complete the DXA, and 9 did not complete blood measures.

Descriptive characteristics of the sample are displayed in Table 1. Over half of adolescents were white (57.4%), with 37.0% African American and 5.6% other. About half of participants were girls (54.2%) and the majority were in school term during measurements (59.0%) whereas the others were on school holiday. Approximately half met the sleep guideline (51.8%) and one behavior guideline (47.0%). The top quintile (20%) of HEI was pre-selected as meeting the diet guideline. Few met the physical activity guideline (11.6%) or 2+ guidelines (18.0%). In those who met two guidelines (n=44), the majority met both sleep and diet guidelines (n=30), some met physical activity and sleep (n=10), and few met both physical activity and diet (n=4). One adolescent met all three guidelines (0.4%).

Individual Behaviors

As shown in Table 2, additional daily MVPA was associated with multiple cardiometabolic risk factors, total cardiometabolic risk score, and adiposity (p<0.05 for all). Each additional 10 minutes per day of MVPA was associated with a lower BMI percentile by 4.10±0.9 units (p=0.001). Additional sleep minutes were associated with lower risk for elevated waist circumference and total cardiometabolic risk scores (p<0.05 for all). Further, every additional hour of sleep (60 minutes) was associated with a lower BMI percentile by 3.6±1.8 units (p=0.04) and lower body fat by 1.2±0.6 percent (p=0.02). Higher dietary quality was associated with lower HOMA-IR risk (p=0.03) but no adiposity measures.

Meeting Individual Guidelines

Meeting the physical activity guideline was associated with lower individual and total cardiometabolic risk scores (p<0.05 for all, Table 3), and lower adiposity measures (p<0.003 for all). Those who met the dietary guideline had a lower HOMA-IR compared to those who did not meet the dietary guideline (p=0.05).

Meeting Multiple Behavior Guidelines

Those who met 2+ guidelines had lower waist circumference, HOMA-IR, and total cardiometabolic risk score (p<0.05 for all, Table 4) compared to those who met zero guidelines. Additionally, those who met 2+ guidelines had lower adiposity measures compared to those who met zero guidelines (p<0.05 for all).

Sensitivity Analysis

A subgroup analysis was conducted with those who contributed three days of dietary intake (n=135). The top quintile HEI score based on this subgroup was 62.3, comparable to the original analysis. Compared to the full analytic sample, more of this sample met the physical activity guideline (14.8%) but a similar amount met the sleep guideline (51.1%). There was a similar distribution for number of guidelines met (34.0% met zero guidelines, 46.7% met one guideline, and 19.3% met 2+ guidelines). For individual behaviors, daily sleep and diet were no longer associated with cardiometabolic risk scores (p>0.05 for all). Daily physical activity associations continued. For individual guidelines, meeting the dietary guideline was no longer associated with HOMA-IR risk (β=−0.21, SE=0.25, p=0.40), and meeting the physical activity guideline was no longer associated with MAP (β=−0.45, SE=0.24, p=0.07) and HOMA-IR risk (β=−0.40, SE=0.29, p=0.17). Meeting the physical activity guideline was still associated with lower adiposity (p<0.05 for all). The associations between 2+ guidelines with lower HOMA-IR (β=−0.31, SE=0.28, p=0.29) and total cardiometabolic risk score (β=−1.09, SE=0.75, p=0.16) were not sustained, whereas the associations with waist circumference (β=−0.53, SE=0.23, p=0.02) and adiposity remained (BMI Percentile: β= −21.4, SE=7.06, p=0.002; body fat percent: β=−4.83, SE=2.37, p=0.04; VAT: β=−0.24, SE=0.10, p=0.02).

DISCUSSION

The objective of this study was to examine the collective influence of meeting the physical activity, sleep, and dietary guidelines on cardiometabolic risk factors and adiposity, as these behaviors may be interrelated. Each behavior was related to cardiometabolic risk and adiposity, independent of the other two behaviors. Adolescents who met multiple guidelines had lower cardiometabolic risk and adiposity. Overall, there was evidence of added benefit from meeting the physical activity, sleep, and dietary guidelines on adolescent health.

In this sample, few met the physical activity guideline (11.6%) as most averaged half of this guideline (34.2±20.6 minutes of MVPA/day). The low prevalence of meeting this guideline may be due to the high proportion of adolescents with overweight and obesity in the current sample (48.6%). A cross-sectional study of adolescents with overweight and obesity (13.1±1.8 years of age) that used objectively measured physical activity found adolescents engaged in 34.4±20.9 minutes of MVPA/day[32] similar to the current study. Physical activity, both duration (minutes/day) and meeting the guideline, was associated with lower total cardiometabolic risk, including lower waist circumference, MAP, HOMA-IR, and adiposity. This study observed an association between meeting the physical activity guidelines and blood pressure (measured as MAP) though there is inconclusive evidence on associations between adolescent physical activity with blood pressure. Prospective cohorts found no association,[33,34] while physical activity interventions of adolescents with obesity demonstrated reductions in blood pressure.[35] The observed association between physical activity and HOMA-IR aligns with prior findings of associations in both prospective[34] and cross-sectional[1] studies.

Physical activity was the only behavior related to adiposity in this sample. In a cross-sectional study of adolescents that used isotemporal substitution analysis, substitution of other movement behaviors (including sedentary behavior, light physical activity, and sleep) for MVPA was associated with higher body fat percentage.[36] Adequate physical activity is important, as multiple associations existed with lower adiposity.

About half of the sample met the sleep guideline, which is higher than investigations using self-report data (31.7%)[15] but comparable to another objectively measured study (52.4%).[10] The average sleep duration (8.7±1.0 hours) is similar to other cross-sectional studies of adolescents using self-report[2] and objectively measured sleep.[17] Sleep might be viewed as having less of an influence relative to the other two behaviors, as over half of this sample met the sleep guideline and the present study found multiple relationships between physical activity and cardiometabolic health. However, additional sleep was associated with lower total cardiometabolic risk, BMI percentile, and body fat, and one individual cardiometabolic risk factor (waist circumference). A cross-sectional study found no relationship between sleep and body fat percentage[2] but did not account for other health behaviors. The present study contributes to the literature that additional sleep minutes were related to lower waist circumference, total cardiometabolic risk, BMI percentile, and body fat, when controlling for other health behaviors.

The HEI score was 47.7±11.1 in this sample, which is low but comparable to other populations of 9 to 13 years of age (46.8±34.9)[37] and 16 to 18 years of age (49.2±12.0).[3] Regardless of dietary quality, those who scored ≥63.0 had a lower HOMA-IR risk score, which is similar to another cross-sectional study in adolescents.[5] Other samples found associations between higher quartiles of HEI score and lower metabolic syndrome prevalence,[11,13] though there was no association between HEI score and total cardiometabolic risk in the current study. One reason for this discrepancy may be that in the present study, total cardiometabolic risk was a composite score based on 5 risk factors, unlike the other study, which used meeting a minimum of 3 of 5 risk factor standards for metabolic syndrome. Prior studies demonstrated that specific food components, including higher intake of fruits and vegetables[3] and less fast food,[11] are associated with lower cardiometabolic risk. The low HEI score of this sample points to the need for further fine-tuned analysis of dietary components and their potential relationship with other health behaviors.

Those who met 2+ guidelines had lower total cardiometabolic risk and adiposity than those who met zero guidelines. Only one third of the 2+ guidelines group met the physical activity guideline (15/45, 33%), but most met the sleep guideline (41/45, 90%). The association of meeting more guidelines with lower cardiometabolic risk and adiposity may point towards the interrelationships of these behaviors[2,17] and their collective effect on adolescent health.

Strengths of the current study include the use of objectively measured physical activity and sleep via accelerometry, the measurement of VAT, and the breadth of measures (clinical measures, anthropometry, DXA, and MRI). A limitation was the range of HEI scores within the sample. One option for reporting HEI score is by grades (score of 90–100 would be an “A”, etc.),[38] though the majority of this sample would report an “F” (score of 59.0 or lower). Other classification options were not appropriate for the data; e.g., classifying HEI scores of below 50, 51–79, and 80 or above, yielded insufficient sample size per category, as only one adolescent scored above 80. Using the top quintile may inappropriately represent this sample meeting the dietary guideline, and other metrics may be used to evaluate diet quality. In general, a higher HEI score is representative of a healthier diet, and healthier diets should be encouraged for all. The main limitation is the cross-sectional nature of the study, and causal relationships cannot be evaluated. Finally, obesity is a complex disease and other genetic and biological factors can influence development of excess weight and adiposity.

Future research should incorporate screen-time, another important behavior that is typically spent sedentary. The Canadian 24-Hour Movement Guidelines were recently released, which include similar guidelines for physical activity and sleep,[39] but the third guideline is screen-time rather than diet. Television viewing is associated with higher cardiometabolic risk and adiposity in children and adolescents,[29] and meeting more of these movement guidelines (physical activity, sleep, and screen-time) is associated with lower cardiometabolic risk and VAT.[10] For diet, investigation into HEI components may determine which specific dietary components influence cardiometabolic risk and adiposity. There is a need for longitudinal assessment of adequate physical activity, sleep, and diet with subsequent cardiometabolic health and adiposity. The current study utilized cross-sectional data and unable to evaluate prospective associations. Finally, the authors acknowledge that adiposity is one component of health but the effects of all three behaviors combined with other factors can extend to other psychosocial benefits, such as improved quality of life, which are important for adolescent health.[40]

Daily physical activity, sleep, and diet contributed individually and collectively to cardiometabolic risk and adiposity in adolescents. Attaining adequate amounts of multiple behaviors provided additional benefit. Low guideline attainment emphasizes the improvement of all three behaviors for adolescents' health promotion. Future research should focus on the interconnectivity of these behaviors to design behavioral approaches to concurrently facilitate adequate amounts of physical activity, sleep, and diet.

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List of Abbreviations:

ASA	Automated Self-Administered
BMI	Body Mass Index
DBP	Diastolic blood pressure
DXA	dual x-ray absorptiometry
HDL-C	High density lipoprotein cholesterol
HEI	Healthy Eating Index
HOMA-IR	Homeostasis assessment model of insulin resistance
MAP	Mean arterial pressure
MRI	Magnetic resonance imaging

MVPA	Moderate-to-vigorous physical activity
SBP	Systolic blood pressure
VAT	Visceral adipose tissue

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Table 1.

Descriptive characteristics of sample (*n*=251)

	Mean	SD	%
Demographics			
Age (years)	12.5	1.9	
Male			45.8
Race			
White			57.4
African American			37.0
Other			5.6
Household Income			
Less than $29,999			8.8
$30,000 – 69,999			26.7
$70,000 – 139,999			34.2
$140,000 or more			23.9
Missing/ Refused			6.4
In School (vs. on school holiday)			59.0
Behaviors			
MVPA (minutes/day)	34.2	20.6	
Sleep (hours/day)	8.7	1.0	
HEI Total Score	47.7	11.1	
Guidelines Met			
Physical Activity			11.6
Sleep			51.8
Diet			20.0
0			35.0
1			47.0
2+			18.0
Cardiometabolic Risk Factors			
Waist circumference (cm)	78.4	17.9	
Systolic Blood Pressure (mmHg)	106.9	9.0	
Diastolic Blood Pressure (mmHg)	65.5	8.9	
High Density Lipoprotein-C (mg/dL)	53.6	11.6	
Triglycerides (mg/dL)	75.7	50.5	
HOMA-IR[^]	2.7	4.5	
Adiposity			
BMI Percentile	70.7	30.2	
BMI Classification			
Underweight			3.2
Normal			48.2
Overweight			14.7
Obese			33.9

	Mean	SD	%
Body Fat (%)	34.2	10.4	
Visceral Adipose Tissue (L)	0.6	0.5	

^HOMA-IR: homeostasis assessment model of insulin resistance

Table 2.

Associations among daily Physical Activity, Sleep, and Diet Quality with Adiposity and Standardized Cardiometabolic Risk Factors in Adolescents (*n*=251)^

	Physical Activity (MVPA minutes)			Sleep (Sleep minutes)			Diet (HEI Total Score)		
	Beta	*SE*	*p*-value	Beta	*SE*	*p*-value	Beta	*SE*	*p*-valu
Adiposity									
BMI Percentile	−0.41	0.09	0.001*	−0.06	0.03	0.04*	−0.23	0.16	0.16
Body Fat (%)	−0.15	0.03	0.001*	−0.02	0.01	0.02*	−0.05	0.05	0.33
Visceral Adipose Tissue (liters)	−0.006	0.001	0.001*	−0.001	0.0004	0.10	−0.004	0.002	0.11
Standardized Cardiometabolic Risk Score$									
Waist Circumference	−0.01	0.003	0.003*	−0.002	0.00	0.008*	−0.007	0.005	0.22
Mean Arterial Pressure	−0.008	0.003	0.007*	−0.001	0.001	0.21	−0.002	0.005	0.59
High Density Lipoprotein Cholesterol#	−0.006	0.003	0.06	−0.001	0.001	0.12	0.004	0.005	0.47
Triglycerides	−0.006	0.003	0.05	−0.002	0.001	0.05	0.001	0.005	0.85
HOMA-IR	−0.01	0.003	0.001*	−0.002	0.001	0.06	−0.01	0.005	0.03*
Total Cardiometabolic Risk	−0.04	0.01	0.001*	−0.01	0.003	0.003*	−0.01	0.01	0.36

^Assessed using linear regression with adjustment for race, age, sex, in-school status, and other behaviors;

*p<0.05;

$Scores represent standardized residuals of each component,

#Reverse coded, as in those with a lower risk had a higher HDL-C level for their age and sex.

Table 3.

Association among Meeting the Physical Activity, Sleep, and Diet Guidelines with Adiposity and Standardized Cardiometabolic Risk Factors in Adolescents (*n*=251)^

	Met Physical Activity Guideline			Met Slee Guideline			Met Diet Guideline		
	Beta	***SE***	***p*-value**	**Beta**	***SE***	***p*-value**	**Beta**	***SE***	***p*-valu**
Adiposity									
BMI Percentile	−21.4	5.90	0.001*	−4.06	3.80	0.29	−4.39	4.65	0.34
Body Fat (%)	−6.92	1.95	0.006*	−0.62	1.28	0.62	−1.81	1.56	0.24
Visceral Adipose Tissue (liters)	−0.28	0.08	0.003*	−0.006	0.06	0.91	−0.13	0.07	0.09
Standardized Cardiometabolic Risk Score$									
Waist Circumference	−0.52	0.019	0.008*	−0.12	0.12	0.31	−0.12	0.15	0.42
Mean Arterial Pressure	−0.41	0.19	0.04*	−0.07	0.12	0.57	−0.01	0.15	0.95
High Density Lipoprotein Cholesterol#	−0.26	0.21	0.21	−0.05	0.13	0.71	0.01	0.16	0.92
Triglycerides	−0.38	0.20	0.07	−0.04	0.13	0.76	−0.04	0.16	0.79
HOMA-IR	−0.48	0.20	0.02*	−0.01	0.13	0.90	−0.35	0.16	0.03*
Total Cardiometabolic Risk	−2.07	0.64	0.002*	−0.30	0.42	0.47	−0.50	0.52	0.34

^ Assessed using linear regression with adjustment for race, age, sex, in school status, and other guidelines

* $p<0.05$;

$ Scores represent standardized residuals of each component,

Reverse coded, as in those with a lower risk had a higher HDL-C level for their age and sex.

Table 4.

Associations among Number of Guidelines Met with Adiposity and Standardized Cardiometabolic Risk Factors in Adolescents (n=251)[^]

	No Guidelines			1 Guideline			2 + Guidelines		
	Beta	***SE***	***p*-value**	**Beta**	***SE***	***p*-value**	**Beta**	***SE***	***p*-value**
Adiposity									
BMI Percentile	Ref	Ref	Ref	−4.55	4.16	0.27	−13.87	5.45	0.01 *
Body Fat (%)	Ref	Ref	Ref	−0.69	1.38	0.62	−4.43	1.80	0.01 *
Visceral Adipose Tissue (liters)	Ref	Ref	Ref	−0.01	0.06	0.81	−0.21	0.09	0.01 *
Standardized Cardiometabolic Risk Score[$]									
Waist Circumference	Ref	Ref	Ref	−0.18	0.13	0.18	−0.37	0.17	0.04 *
Mean Arterial Pressure	Ref	Ref	Ref	−0.09	0.13	0.50	−0.18	0.18	0.29
High Density Lipoprotein Cholesterol[#]	Ref	Ref	Ref	−0.08	0.14	0.58	−0.11	0.18	0.59
Triglycerides	Ref	Ref	Ref	0.01	0.14	0.91	−0.23	0.18	0.23
HOMA-IR	Ref	Ref	Ref	−0.09	0.14	0.56	−0.45	0.19	0.02 *
Total Cardiometabolic Risk	Ref	Ref	Ref	−0.42	0.46	0.36	−1.35	0.61	0.02 *

[^] Assessed using linear regression with adjustment for race, age, sex, and in school status,

[*] $p<0.05$;

[$] Scores represent standardized residuals of each component

[#] Reverse coded, as in those with a lower risk had a higher HDL-C level for their age and sex.