



# Income, Race and its Association with Obesogenic Behaviors of U.S. Children and Adolescents, NHANES 2003–2006

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## Abstract

**Objectives** To describe the associations of income and race with obesogenic behaviors and % body fat among a large sample of U.S. children and adolescents.

**Design** Data were obtained from the 2003–2004 and 2005–2006 National Health and Nutritional Examination Survey. Multiple linear regression models and interactions were used to examine the associations of moderate-to-vigorous physical activity (MVPA), sedentary time, diet quality, and screen-time with income-to-poverty ratio and race. Separate stratified analyses explored associations among individual obesogenic behaviors within race and income groups.

**Results** This study included children and adolescents ( $n=3551$ , mean = 13.1 years,  $SD=3.9$  years) who were 37% Hispanic, 27% White, and 35% Black. Overall, Hispanic children/adolescents had significantly higher levels of adiposity (3.6, 95 CI = 0.9, 6.3) than white children and adolescents. Medium-income children and adolescents engaged in less MVPA (−3.3 min, 95 CI = −5.1, −1.5), had poorer diet quality (−1.1, 95 CI = −1.9, −0.2), and used screens less (−33.9 min, 95 CI = −45.4, −22.4) than children and adolescents from low-income households. High-income children and adolescents also engaged in less MVPA (−3.1 min, 95 CI = −5.5, −0.7) and used screens less (−62.9 min, 95 CI = −78.3, −47.4) than children and adolescents from low-income households. However, there were significant race/ethnicity-by-income interactions for high-income Hispanic children and adolescents with diet quality (−3.5 HEI-2010 score, 95 CI = −6.6, −0.4) and screen time (66.9 min, 95 CI = 24.7, 109.0). There was also a significant race/ethnicity-by-income interaction for the screen-time of Black children and adolescents from medium (33.8 min, 95% CI 0.2, 67.3) and high (75.8 min, 95% CI 34.7, 117.0) income households.

**Conclusions** There appears to be a complex relationship that varies by race/ethnicity between income, obesogenic behaviors, and adiposity levels among children and adolescents. More work is needed to identify the behavioral mechanisms that are driving disparate rates of overweight and obesity among minority children and those from low-income households.

**Keywords** Obesity · Youth · Physical activity · Diet · Screen time · Adiposity

## Introduction

Childhood obesity is an international “public health epidemic” [37, 43, 55]. The prevalence of overweight and obesity among children and adolescents (6–19 years) is at an all-time high in the United States (U.S.) [45]. Obesity has been linked to a variety of non-communicable diseases including abnormal fasting glucose, insulin resistance, type 2 diabetes, hypertension, sleep apnea, and asthma [4, 40]. A mounting body of evidence has examined the intersections between race and socioeconomic position (i.e., commonly measured by household income) on a myriad of health outcomes [1, 5, 11, 20, 28, 34, 58]. Studies have identified longitudinal

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trends in childhood and adolescent overweight or obesity and the relationship to income from birth to adulthood [26, 31]. In the U.S., children and adolescents from low-income families are more likely to be overweight or obese by age 5 than their high-income counterparts [10, 14, 25, 31, 32, 51] and the relationship between income and obesity may vary between racial/ethnic groups [18, 19, 31, 49].

Obesity is a multifactorial condition influenced by social, environmental, and genetic determinates [34]. Modifiable obesogenic behaviors such as moderate-to-vigorous physical activity (MVPA), sedentary behaviors, diet quality, and screen time play a large role in determining weight status. Examining differing levels of engagement in obesogenic behaviors by race and income-level might uncover important targets for intervention with the potential to reduce or eliminate income and race/ethnicity related disparities in overweight and obesity. The objective of this study was to examine the association between income, race, and four obesogenic behaviors using 2 waves (2003–2004 and 2005–2006) from the National Health and Nutrition Examination Survey (NHANES).

## Methods

### Sample

NHANES is a repeated cross-sectional study conducted in 2-year cycles and collects data on a nationally representative

sample of the U.S. noninstitutionalized population. Trained staff members conduct both interviews and examinations throughout the U.S. A more detailed description of NHANES is available elsewhere [8, 30]. This study includes data from the 2003–2004 and 2005–2006 waves of NHANES. These years of data collection were selected because they include objective measures of physical activity, sedentary behaviors, and adiposity measured via dual X-ray absorptiometry (DXA) in addition to measuring diet intake and screen-time. Following standard protocols using NHANES data, participants were excluded if they were younger than 6 or older than 19 years. Participants were included if they had valid data from all four obesogenic behavior measures (i.e. MVPA, sedentary time, dietary intake, and screen-time). Descriptive characteristics of the sample can be found in Table 1.

## Measures

### Physical Activity and Sedentary Time

The physical activity monitor, Actigraph (Actigraph, LLC; Ft. Walton Beach, FL) model 7164 accelerometer was placed on the right hip attached to an elastic belt for a 7-day wear period. Participants were asked to wear the device while they were awake and to take it off only for swimming and bathing. Monitors were then returned by express mail to the NHANES contractor, where data were downloaded, and the device was checked to determine whether it was still

**Table 1** Sample characteristics of children and adolescent aged 6–19, NHANES 2003–2006

Variable	All	Low income (PIR < 1.00)	Medium income (PIR 1.00–4.00)	High income (PIR > 4.00)	Missing income
Total, n (%)	3551 (100)	1042 (29.3)	1797 (51.0)	567 (15.9)	145 (4.1)
Age, years ( $\pm$ SD)	13.1 $\pm$ 3.86	13.3 $\pm$ 4.0	12.9 $\pm$ 3.8	13.1 $\pm$ 3.7	13.8 $\pm$ 3.8
Sex, n (%)					
Boys	1778 (50.1)	493 (47.3)	918 (51.1)	286 (50.4)	81 (55.9)
Girls	1773 (49.9)	549 (52.7)	879 (48.9)	281 (49.6)	64 (44.1)
Race/ethnicity, n (%)					
Hispanic	1346 (37.9)	468 (44.9)	693 (38.6)	123 (21.7)	62 (42.8)
White	965 (27.2)	140 (13.4)	499 (27.8)	301 (53.1)	25 (17.2)
Black	1240 (34.9)	434 (41.7)	605 (33.7)	143 (25.2)	58 (40.0)
Obesogenic behaviors					
MVPA (mins) $\pm$ SD	40.4 $\pm$ 26.5	42.0 $\pm$ 27.1	40.0 $\pm$ 26.5	39.7 $\pm$ 26.0	38.9 $\pm$ 23.7
Sedentary (mins) $\pm$ SD	498.2 $\pm$ 162.2	500.7 $\pm$ 168.8	493.6 $\pm$ 161.1	504.3 $\pm$ 148.8	515.0 $\pm$ 178.4
HEI-2010 $\pm$ SD	44.1 $\pm$ 11.1	44.5 $\pm$ 10.8	43.6 $\pm$ 11.1	44.8 $\pm$ 11.8	44.1 $\pm$ 11.2
Screen (mins) $\pm$ SD	264.8 $\pm$ 152.9	292.6 $\pm$ 155.5	257.9 $\pm$ 150.2	228.3 $\pm$ 148.1	296.8 $\pm$ 145.6
% body fat $\pm$ SD	29.4 $\pm$ 8.8	30.0 (8.9)	29.4 (8.9)	28.0 (7.9)	29.2 (9.5)

Participants included in all obesogenic analysis had full data including valid accelerometer, dietary intake, and screen time measurements (N = 3551)

% body fat measured by the dual energy X-ray (DXA) included (3,133) children with valid accelerometer, dietary intake, and screen time measurements

within the manufacture's calibration specifications. Participants whose monitors were not calibrated when returned were excluded. For this study, consistent with previously published protocols [53], a valid day was defined as having 10 or more, hours of monitor wear. Wear time was defined by subtracting non-wear time (defined as 60 or more minutes of consecutive accelerometer counts of zero) from 24 (hours in a day) [53]. Participants were included if they had 4 or more valid days of wear, with at least one valid day occurring on a weekend. Cut points associated with sedentary behaviors [38] and MVPA [16] in children and adolescents were applied to the data to distill the amount of minutes per day spent in each activity level.

### Screen-Time

Screen time included television, video, and computer game use, and was ascertained as part of the physical activity questionnaire [52], which was completed during a home interview. Participants reported separately, the number of hours during a typical day in the past 30 days that they watched television and/or used a computer (including video gaming consoles). Responses included 'none', '< 1 h', '1 h', '2 h', '3 h', '4 h', or '5 or more hours'. Response categories for hours of computer use included '< 1 h', '1 h', '2 h', '3 h', '4 h', or '5 h'. Hours of television and computer use were summed to ascertain an estimation of overall screen use. Self-reported screen time has been established as a valid and reliable predictor of cardiometabolic risk factors, such as obesity [21, 50]. Values that exceeded 480 min (8 h of daily screen use) were considered implausible and were converted to 480 min.

### Dietary Intake

Dietary intake was obtained using two multiple pass 24-h dietary recall interviews conducted by trained research staff on 2 days in 1 week [6]. All 24-h recalls underwent a four-step quality assurance process to evaluate the overall completeness, acceptability, and plausibility of reported dietary intakes. Dietary recalls that met the minimum criteria for intakes collected with the Automated Multiple Pass Method were analyzed [2]. Responses from the dietary recall were then converted to Healthy Eating Index-2010 (HEI) scores via codes provided by the National Cancer Institute for participants with two nonconsecutive days of complete dietary data [22]. Additionally, children and adolescents who were under the age of 8 used a parent proxy when recalling their dietary intake. The HEI is a measure of diet quality that assesses conformance to the Dietary Guidelines for Americans, which is the basis of nutrition policy for the U.S. government and the foundation of federal nutrition guidance [22, 39].

The HEI is comprised of 12 components including: (1) total fruit; (2) whole fruit; (3) total vegetables; (4) greens and beans; (5) whole grains; (6) dairy; (7) total protein; (8) seafood and plant protein; and (9) ratio of unsaturated to saturated fatty acids; (10) refined grains; (11) sodium; and (12) empty calories (i.e., energy from solid fats, alcohol, and added sugars) [23]. For all components, higher scores reflect better diet quality. Component scores are summed and HEI total scores range from 0 to 100 [23].

### Adiposity

Whole body (DXA) scans were performed during NHANES 1999–2006. Scans were acquired using a Hologic QDR 4500A fan-beam densitometer (Hologic, Inc., Bedford Massachusetts) among participants at least 8 years of age. Previous studies have reported the reliability and precision estimates using this device [7, 27, 35]. DXA scans are reviewed for quality using standardized protocols, and invalid DXA data were reclassified as missing values. To account for missingness that was associated with participant age, weight, and height, sequential regression multivariate imputation (SRMI) was performed. Detailed procedures and protocols regarding imputations have been described elsewhere [8, 48]. For the purposes of this study, we focused on total % body fat.

### Income-to-Poverty-Ratio

The income-to-poverty ratio is a ratio that represents the ratio of household income to poverty and is calculated by dividing the total reported household income by the Department of Health and Human Services' poverty level [13]. For example, an income-to-poverty ratio of 0.5, indicates that a household is earning an equivalent of 50% the amount of income as the federally established poverty level, while an income-to-poverty ratio of 1.5 indicates that a household is earning 150% of the federally established poverty level. For this study, each participant was classified as low, medium, or high based upon their household income-to-poverty ratio. Classifications align with previous literature [18] and were created as follows. If a child's household received an income-to-poverty ratio of 0.00–1.00, the child was assigned to the low-income group. Likewise, children and adolescents living in a household with an income-to-poverty ratio of 1.01–4.00 were assigned to the medium-income group and children and adolescents living in households above 4.00 on the income-to-poverty ratio were classified as high-income.

### Race/Ethnicity

Race/ethnicity of children and adolescents was collected via parent proxy report. In order to align with previous

work using the NHANES datasets [9], a stepwise process for designating children and adolescents into race/ethnicity categories was employed. First, children and adolescents whose parent/guardian designated them as Hispanic or Mexican American were categorized as Hispanic regardless of race. Next, children and adolescents who were designated as Black and had not been assigned to Hispanic category were assigned to the Black category. Next, children and adolescents who were designated as White and had not been assigned to another category were assigned to the non-Hispanic White category. Finally, children and adolescents that were not assigned to any of the previous categories were assigned to the Other race/ethnicity category.

### Statistical Analyses

Analyses were performed in Stata (v14.2 StataCorp College Station, Texas). The relationship between race/ethnicity, income, the four obesogenic behaviors of interest (i.e., MVPA, sedentary time, screen time, and diet quality) and % body fat was examined using a multi-step analysis. First, to examine the relationship of the income-to-poverty (i.e. low, medium, and high), four obesogenic behaviors, and % body fat, separate linear and regression models were conducted using income as the independent variable. This model allowed for the evaluation of the association of income with obesogenic behaviors and % body fat for all children and adolescents in the sample before adding the additional covariates. Second, to examine the relationship of, income, the four obesogenic behaviors, and % body fat whilst adding race (i.e. White, Black, and Hispanic), separate linear regression models were estimated for each behavior and adiposity outcome. In these models, either the behavior of interest or % body fat served as the dependent variable and income-to-poverty ratio was the independent variable. Age, sex, race/ethnicity, and all possible race/ethnicity-by-income-level interaction terms were included as covariates. Low-income and White were used as the reference categories. Henceforth this approach is referred to as “model 2”. Third, an additional stratified analysis was conducted to expand upon and/or confirm the findings of the full model. In this analysis a separate linear regression model was estimated for each race/ethnicity group, obesogenic behavior, and adiposity status. In these models, either the behavior of interest or % body fat was the dependent variable and income-to-poverty ratio was the independent variable with age and sex included as covariates. Finally, a fourth stratified additional analysis was conducted with separate linear regression models estimated for each income level (i.e., low, medium, high), obesogenic behavior, and adiposity status. In these models the behavior of interest or weight outcome was the dependent variable and race/ethnicity was the independent variable. Age and sex were included as covariates.

### Results

Descriptive and sociodemographic information of the final sample are shown in Table 1. The final sample included ( $N = 3551$ ) children and adolescents. Children and adolescents in the Other race/ethnicity category were excluded from analyses due to inadequate sample size with valid data ( $n = 162$ ). A subset of children and adolescents with valid DXA data and measures of all obesogenic behaviors included ( $n = 3132$ ) participants. The mean age of the participants in the final sample was 13.1 years ( $SD = 3.9$ ) and 50.1% were male. Overall, 17.8% and 21.2% of the final sample were either overweight or obese respectively.

The results of the linear regression models analyzing the association of income, race, and the interaction of race and income with adiposity and obesogenic behaviors can be found in Table 2. The initial linear model (model 1) with no covariates indicated high-income children and adolescents had significantly less adiposity when compared to their low-income peers ( $-2.2$  95% CI  $-3.5, -0.8$ ). The linear regression models indicated that low-income children and adolescents engaged in significantly more MVPA than their medium ( $-3.3$  min 95% CI  $-5.1, -1.5$ ) and high-income ( $-3.1$  min 95% CI  $-5.5, -0.7$ ) counterparts. Medium-income children and adolescents had significantly poorer diet quality ( $-1.1$  HEI-2010 score 95% CI  $-1.9, -0.2$ ) than their low-income counterparts. Low-income children and adolescents also engaged in more screen-time than their medium ( $-33.9$  min 95% CI  $-45.4, -22.4$ ) and high-income ( $-62.9$  min 95% CI  $-78.3, -47.4$ ) counterparts. There were no statistically significant associations between income-to-poverty-ratio and sedentary time.

Model 2 used the income-to-poverty ratio as the independent variable while adding race, race/ethnicity-by-income interactions, age, and sex as covariates. Results of the linear model indicated that the proportion of body fat for Hispanic children and adolescents were significantly less (3.6 95% CI 0.9, 6.3) when compared to their White peers. No race/ethnicity-by-income interactions reached statistical significance in the MVPA regression model. For HEI, there was a statistically significant race/ethnicity-by-income interaction for high-income Hispanic children and adolescents ( $-3.5$  HEI-2010 95% CI  $-6.6, -0.4$ ). The Hispanic by high-income (66.9 min 95% CI 24.7, 109.0), Black by medium-income (33.8 min 95% CI 0.2, 67.3), and Black by high-income (75.8 min 95% CI 34.7, 117.0) interactions were all statistically significant for screen time.

In the third model (Table 3), stratifying groups by race, results indicated that income was not associated with body adiposity. Within the logistic regression models, no

**Table 2** Multiple linear regressions examining race and income's association with % body fat and four obesogenic behaviors

Variable	Ref	% Body Fat	95% CI	(MVPA) mins	95% CI	Sedentary (mins)	95% CI	HEI-2010	95% CI	Screen Time (mins)	95% CI					
<b>Model 1</b>																
<i>Constant</i>		30.0	29.1	30.8	42.7	41.3	44.1	497	487.8	506.2	44.6	43.9	45.3	293	283.9	302.2
Medium	Low-income	-0.7	-1.8	0.3	-3.3	-5.1	-1.5	-0.4	-11.9	11.2	-1.1	-1.9	-0.2	-33.9	-45.4	-22.4
High	Low-income	-2.2	-3.5	-0.8	-3.1	-5.5	-0.7	6.7	-8.7	22.2	0.3	-0.9	1.4	-62.9	-78.3	-47.4
<b>Model 2</b>																
<i>Constant</i>		28.4	25.9	30.8	37.1	33.3	40.9	502.7	477.6	527.8	42.9	41.1	44.7	287.2	262.4	311.9
Medium	Low-income white	0.4	-2.2	3.1	-1	-5.3	3.4	-11.7	-40.3	16.8	-0.7	-2.8	1.3	-55.1	-83.1	-27.1
High	Low-income white	-1.1	-3.9	1.7	0.7	-3.9	5.4	-3.8	-34.3	26.7	2.2	0	4.4	-94.1	-124	-64.1
High	Medium-income white	-1.5	-3.4	0.4	1.7	-1.6	5	8.5	-13.1	30.1	2.9	1.3	4.5	-39	-60.3	-17.6
Hispanic	White	3.6	0.9	6.3	2.8	-1.6	7.1	-4.1	-32.7	24.4	4.4	2.7	5.8	2	-26.2	30.2
Black	White	-0.2	-2.9	2.6	10.8	6	15.5	-9.2	-38	19.7	-0.7	-2.8	1.3	12	-16.4	40.5
Black	Hispanic	-3.8	-2.9	2.6	7.6	4.6	10.6	-5	-24.8	14.7	-5.2	-6.6	-3.7	10	-9.5	29.6
Hispanic-x-medium-income <sup>a</sup>	Low-income white	-1.5	-4.5	1.5	0.5	-4.6	5.6	1.2	-32.3	34.6	-1.4	-3.8	1	28.2	-4.9	61.2
Hispanic-x-high-income <sup>a</sup>	Low-income white	-0.4	-0.4	3.3	-0.1	-6.6	6.4	10.4	-32.3	53.1	-3.5	-6.6	-0.4	66.9	24.7	109
Black-x-medium-income <sup>a</sup>	Low-income white	-0.7	-3.8	2.4	-4.5	-9.7	0.7	25.3	-8.6	59.3	1.2	-1.3	3.6	33.8	0.2	67.3
Black-x-high-income <sup>a</sup>	Low-income white	-1.1	-4.8	2.6	-5.8	12.15	0.5	15.47	26.19	57.1	-1	-4	2	75.8	34.7	117

Bold values indicate significant findings (p<0.05)

Models controlled for age and sex

<sup>a</sup>Interaction between income level and racial/ethnic group

**Table 3** Additions linear regressions examining race and income's association with % body fat and four obesogenic behaviors stratified by race/ethnicity

Model 3	Ref	Hispanic		White		Black	
		Coef	95% CI	Coef	95% CI	Coef	95% CI
% body fat							
<i>Constant</i>		31.8	30.6	33	26.1	28.2	29.7
Medium-income	Low-income	-0.9	-2.4	0.6	-2.4	-0.3	-2.0
High-income	Low-income	-1.3	-3.6	1.0	-4.0	-2.2	0.4
High-income	Medium-income	-0.4	-2.6	1.8	-3.2	-1.9	0.5
MVPA (mins)							
<i>Constant</i>		39.8	37.9	41.9	33.1	47.8	50.1
Medium-income	Low-income	-0.4	-2.9	2.2	-4.7	-5.9	-2.8
High-income	Low-income	0.6	-3.7	5.0	-3.3	-5.4	-0.7
High-income	Medium-income	1.0	-3.2	5.2	-1.4	0.5	5.0
Sedentary time (mins)							
<i>Constant</i>		498.4	485.2	511.6	476.3	493.5	507.6
Medium-income	Low-income	-9.1	-26.2	7.9	-41.3	14.5	33.0
High-income	Low-income	8.6	-20.3	37.4	-34.8	13.4	41.7
High-income	Medium-income	17.7	-10.2	45.6	-14.5	-1.2	26.1
HEL-2010 score							
<i>Constant</i>		47.3	46.3	48.3	40.9	42.2	43.1
Medium-income	Low-income	-2.1	-3.4	-0.8	-2.9	0.4	1.7
High-income	Low-income	-1.3	-3.5	0.9	-0.1	1.1	3.1
High-income	Medium-income	0.8	-1.4	2.9	1.2	0.7	2.6
Screen time (mins)							
<i>Constant</i>		289.1	275	303.2	263.2	299.5	313.3
Medium-income	Low-income	-26.8	-44.9	-8.6	-82.4	-20.9	-2.9



**Table 4** Additions linear regressions examining race and income's association with % body fat and four obesogenic behaviors stratified by income level

Model 4	Ref	Low-income			Medium-income			High-income		
		Coef	95% CI		Coef	95% CI		Coef	95% CI	
% body fat										
	<i>Constant</i>	28.5	25.8	31.1	28.8	27.5	30.0	27.3	26.0	28.6
	Hispanic White	3.3	0.3	6.2	2.1	0.6	3.7	<b>3.2</b>	<b>1.0</b>	<b>5.5</b>
	Black White	-0.3	-3.3	2.7	-0.9	-2.5	0.7	-1.4	-3.6	0.9
	Black Hispanic	<b>-3.6</b>	<b>-5.4</b>	<b>1.8</b>	<b>-3.1</b>	<b>-4.5</b>	<b>-1.7</b>	<b>-4.6</b>	<b>-7.2</b>	<b>-2.0</b>
MVPA (mins)										
	<i>Constant</i>	36.9	32.9	40.8	36.1	34.1	38.1	37.9	35.3	40.4
	Hispanic White	3	-1.5	7.5	<b>3.3</b>	<b>0.7</b>	<b>5.9</b>	2.7	-1.9	7.4
	Black White	<b>10.5</b>	<b>5.9</b>	<b>15</b>	<b>5.9</b>	<b>3.2</b>	<b>8.7</b>	<b>4.6</b>	<b>0.2</b>	<b>9.0</b>
	Black Hispanic	<b>7.5</b>	<b>4.4</b>	<b>10.6</b>	<b>2.7</b>	<b>0.2</b>	<b>5.2</b>	1.9	-3.4	7.3
Sedentary time (mins)										
	<i>Constant</i>	504.4	477.9	530.9	492.3	479	505.5	500.9	485.3	516.5
	Hispanic White	-5.5	-35.7	24.5	-2.9	-20.3	14.4	6.1	-22.9	35
	Black White	-10.2	-40.5	20.2	16.8	-1.1	34.8	5.7	-21.8	33.2
	Black Hispanic	-4.6	-25.4	16.2	<b>19.8</b>	<b>3.3</b>	<b>36.2</b>	-0.3	-33.6	32.9
HEI-2010 score										
	<i>Constant</i>	42.9	41.2	44.7	42.9	41.2	43.1	45.1	43.8	46.4
	Hispanic White	<b>4.4</b>	<b>2.4</b>	<b>6.4</b>	<b>3</b>	<b>1.8</b>	<b>4.3</b>	0.9	-1.5	3.4
	Black White	-0.8	-2.8	1.2	0.5	-0.8	1.8	-1.7	-4	0.6
	Black Hispanic	<b>-5.2</b>	<b>-6.6</b>	<b>-3.8</b>	<b>-2.6</b>	<b>-3.8</b>	<b>-1.4</b>	-2.7	-5.5	0.1
Screen time (mins)										
	<i>Constant</i>	287.5	261.7	313.4	232.5	219.5	245.5	193.1	176.9	209.3
	Hispanic White	1.5	-27.9	30.9	<b>30.1</b>	<b>13.1</b>	<b>47</b>	<b>68.9</b>	<b>38.8</b>	<b>99.1</b>
	Black White	12.1	-17.6	41.8	<b>44.9</b>	<b>27.3</b>	<b>62.5</b>	<b>88.1</b>	<b>59.5</b>	<b>116.7</b>
	Black Hispanic	10.5	-9.9	30.9	14.9	-1.3	31	19.2	-15.4	53.8

Bold values indicate significant findings ( $p < 0.05$ )

Models controlled for age and sex

adolescents. Medium-income Black children and adolescents also engaged in more MVPA than medium-income White (5.9 min 95% CI -3.3, 8.7) and Hispanic (2.7 min 95% CI 0.2, 5.2) children and adolescents. When restricting the model to high-income, Black children and adolescents engaged in significantly more MVPA (4.6 min 95% CI 0.2, 9.0) than high-income White children and adolescents. Within low-income children and adolescents, there were no significant association between race and sedentary time. Medium-income Black children and adolescents engaged in significantly more sedentary time (19.8 min 95% CI -3.3, 36.2) than their medium-income Hispanic counterparts. There were no significant associations between race and sedentary time within the high-income group. When analyzing diet quality for low-income children and adolescents only, Hispanics had significantly healthier diet quality (4.4 HEI-2010 score 95% CI 2.4, 6.4) than their low-income White counterparts. Low-income Black children and adolescents had significantly poorer diet quality (-5.2 HEI-2010 score 95% CI -6.6, -3.8) compared to low-income Hispanic children and adolescents. Medium-income Hispanic

children and adolescents had significantly healthier diet quality (3.0 min 95% CI 1.8, 4.3) than medium-income White children and adolescents. Medium-income Black children and adolescents had significantly poorer diet quality (-2.6 min 95% CI -3.8, -1.4) than their medium-income Hispanic counterparts. There were no significant associations between race and diet quality within the high-income group. There were also no significant associations between race and screen time within the low-income group. Medium-income Hispanic children and adolescents used screens significantly more (30.1 min 95% CI -13.1, 47.0) than their medium-income White counterparts. When compared to medium-income White children and adolescents, medium-income Black children and adolescents used screens significantly more (44.9 min 95% CI 27.3, 62.5). High-income Hispanic children and adolescents used screens significantly more (68.9 min 95% CI 38.8, 99.1) than high-income White children and adolescents. High-income Black children and adolescents also used screens significantly more (88.1 min 95% CI 59.5, 116.7) than high-income White children and adolescents.

## Discussion

This study examined the association between income, race, four obesogenic behaviors (MVPA, sedentary time, diet quality, and screen time), and the proportion of adiposity using two waves of national data. With regards to adiposity, this study found, consistent with past work utilizing portions the same data [46], income was protective against the odds of being overweight/obese. We also found that, regardless of race/ethnicity, screen time was lower in middle and high-income households. Interestingly, this study also found that there was an inverse association between income and MVPA. No clear patterns were evident for diet quality or sedentary time by income level. Income appears to have a protective effect on screen use among this population. However, significant race by income interactions demonstrate the associations between income and the obesogenic behaviors measured varied by race/ethnic group. Decreasing sedentary behavior, such as screen use, is a potential intervention lever to reduce overweight and obesity in low-income populations.

When stratifying models by race/ethnicity group, increasing income was associated with a statistically significant decrease in screen time for White children and adolescents. Both children and adolescents who were Hispanic and Black were trending in a similar direction, but the relationships did not reach statistical significance across all income levels. It appears that the association between income and screen time in *model 1* were largely driven by White children and adolescents. Table 3 also highlights that Black children appear to be decreasing their time spent in MVPA as income level increases. This association would also explain the findings in *model 1* that MVPA was inversely associated with income. When restricting the models to each race/ethnicity group, there were not consistent patterns by racial/ethnic group and income with any other obesogenic behavior. With the exception of decreasing sedentary behaviors such as screen time in White children and adolescents, no patterns of relationships were evident within racial/ethnic groups and across income levels.

When stratifying models by income group, Black children and adolescents engaged in statistically significantly more MVPA than their White counterparts across all income levels. Black children and adolescents also engaged in statistically significantly more MVPA than Hispanics in both low- and medium-income groups. It appears here that the inverse associations between income and MVPA seen in *model 1* were largely driven by Black children and adolescents. Across both low- and medium-income levels, Hispanic children and adolescents had healthier diet quality when compared to their White

and Black counterparts. Both Black and Hispanic children and adolescents used screens significantly more as income increased when compared to Whites. This finding informs us that the protective effects of income and screen seen in *model 1* were largely driven by White children and adolescents. These findings suggest that future interventions need to be tailored to individual racial/ethnic groups and children's household income level of the children.

The findings presented herein do not clarify the behavioral mechanisms that appear to be driving the disparities in overweight/obesity or adiposity levels by race/ethnicity and income level that have been previously noted [18, 19, 49]. According to nationally representative samples of U.S. children and adolescents drawn from the same datasets that this study is based upon, Hispanic and Black children and adolescents have the highest prevalence rates of overweight/obesity measured by BMI [44]. Contradictory to the studies previously mentioned, we found that Black children and adolescents have the lowest proportions of adiposity when compared to both White and Hispanic children and adolescents. The present study's findings do not help to explain these earlier findings, as children and adolescents who are Hispanic had the healthiest diet quality according to HEI-2010. In addition to diet, the obesogenic behaviors of Hispanic children and adolescents did not consistently differ from other race/ethnic groups. Similar to previous findings [53], this study found that Black children and adolescents were the most active. Thus, it is unclear why overweight and obesity is more prevalent in these groups when their behaviors and adiposity levels do not seem to indicate increased risk.

Explanations for these unclear relationships between obesogenic behaviors and overweight and obesity risk are broad and potentially complex. First, the disparities in overweight/obesity may be limited by the measurement tool. BMI is an indicator of excess weight, not excess adiposity. Thus, differences in BMI-determined prevalence of overweight and obesity may be due to differences in lean mass rather than fat mass. Several studies have shown that BMI may be a poor measure of obesity in minority children and adolescents [12, 15, 17, 42, 57]. If this is the case, future studies of obesity by race/ethnicity should employ an alternative measure of obesity in order to better link obesogenic behaviors to unhealthy weight in children and adolescents. Alternatively, the current measures of obesogenic behaviors may not be precise enough to elucidate differences that are driving disparate rates of obesity. In this study children and adolescents reported on their diets for only 2 days. Further, MVPA and sedentary time estimates were based on 7 days of accelerometer wear, and screen time was recalled for 30 days prior. The brevity and complexity of some of these time frames for measurements may not fully capture the long-term behaviors of these children and adolescents or how these behaviors

change over time. Recently reliability studies of youth physical activity suggest a minimum of 10 valid days are required to assess youth PA [3]. Finally, sleep was not measured in the current study; however, sleep duration and quality have been associated with obesity in youth [29, 47]. Thus, disparate rates of obesity may be driven by behaviors that are not included in this study.

There are several strengths of this study including the large representative sample and the analysis of four obesogenic behaviors by income and race. This study also employed DXA scan as a measure of adiposity. DXA has been identified as a benchmark measure of adiposity in children and adolescents [24]. Appropriate statistical analyses were conducted with follow up stratified analysis. However, this study is not without limitation. The cross-sectional nature of this study limits the ability to make casual inferences about the relationship between income, race, and the obesogenic behaviors of children and adolescents. Further, the limited number of valid cases in other racial/ethnic groups (e.g., Asian and Native American children and adolescents), this study was only able to explore the relationship of income and race/ethnicity in children and adolescents who are White, Black, and Hispanic. Finally, this study used a single indicator of social disparity (i.e., family income) which may incorrectly classify certain families' socioeconomic status. Future studies should aim to collect multiple indicators of social disparity. Future studies should also work to understand if there are differences between race, income, and locality. Liu and colleagues found that rural children and adolescents were persistently more likely to be overweight and obese, but in some cases engaged in more healthful behaviors than their urban peers [36]. Seasonality also needs to be considered in future studies given the recent finding that summer break is a period of accelerated weight gain [41, 54, 56].

## Conclusion

The findings presented herein did not clearly identify patterns of obesogenic behaviors by race/ethnicity and income among children and adolescents. Additional research is needed using alternative measures of obesity and increased behavioral measurement protocols. Studies employing longitudinal designs need to examine developmental trajectories in obesogenic behaviors and their relationship with risk for obesity by race/ethnicity and income.

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## Compliance with Ethical Standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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