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Child Physical Activity Associations With Cardiovascular Risk Factors Differ by Race

Nicholas M. Edwards,
Division of Sports Medicine, Cincinnati Children's Hospital Medical Center, Cincinnati, OH

Heidi J. Kalkwarf,
Division of Gastroenterology, Hepatology and Nutrition, Cincinnati Children's Hospital Medical Center, Cincinnati, OH

Jessica G. Woo,
Division of Biostatistics and Epidemiology, Cincinnati Children's Hospital Medical Center, Cincinnati, OH

Philip R. Khoury,
Heart Institute, Cincinnati Children's Hospital Medical Center, Cincinnati, OH

Stephen R. Daniels, and
Dept. of Pediatrics, University of Colorado School of Medicine and Children's Hospital Colorado, Aurora, CO

Elaine M. Urbina
Heart Institute, Cincinnati Children's Hospital Medical Center, Cincinnati, OH

Abstract

Purpose: The objective of this study was to characterize the relationship between objectively-measured physical activity (PA) and cardiovascular risk factors in 7-year-old children and test the hypothesis that it differs by race.

Methods: Cross-sectional study of 308 7-year-old children drawn from a major US metropolitan community. PA (moderate-to-vigorous, MVPA; light, LPA; and inactivity, IA) was measured by accelerometry (RT3). Cardiovascular risk factors included BMI, blood pressure, and serum lipids, glucose and insulin concentrations. General linear modeling was used to evaluate the independent associations between PA measures and cardiovascular risk factors and interactions by race.

Results: In black children, greater time spent in PA was independently associated with lower levels of triglycerides (MVPA and LPA, both $p < .01$), glucose (MVPA, $p < .05$), and insulin (MVPA, $p < .01$); these associations were not evident in white children. Across races, greater inactivity was independently associated with greater low-density lipoprotein cholesterol in

Address author correspondence to Nicholas M. Edwards at to drnick@umn.edu.

overweight participants ($p < .01$) but not in normal weight participants. No PA measure was associated with BMI, systolic blood pressure, or high-density lipoprotein cholesterol.

Conclusions: In this cohort of 7-year-old children, the relationship between PA and some cardiovascular risk factors differed by race. These findings may have implications for targeting of PA promotion efforts in children.

Keywords

lipids; blood pressure; body mass index; glucose; accelerometry

Physical activity is an important modifiable factor associated with cardiovascular disease (42). Engaging in higher levels of physical activity is protective against death and myocardial infarction in adults and is associated with healthier levels of cardiovascular risk factors in children and adolescents (18,42).

Differences in physical activity (3) and the prevalence of risk factors (including cholesterol) have been reported between black and white children; black boys have demonstrated higher levels of high-density lipoprotein cholesterol (HDL) and lower levels of triglycerides than white boys (5,31).

The relationships between physical activity, cardiovascular risk factors, and race are not clear. In a 2010 study of 12- to 19-year-old adolescents, Bremer et al. found the relationship between physical activity (measured by questionnaire) and risk factors differed by race and sex as follows: negative association with total cholesterol and triglycerides in white girls, positive association with HDL cholesterol in white participants overall and in black boys, negative association with low-density lipoprotein (LDL) cholesterol and insulin resistance in white boys, and no associations between physical activity and risk factors in black girls (7). Conversely, in a cross-sectional study of 9- to 10-year-old children Owen et al. reported significant associations between physical activity (measured by accelerometer) and lipids with similar strengths of association in all ethnic groups (34). Thus, our aim in this study was to characterize the association between objectively-measured physical activity and cardiovascular risk factors in 7-year-old children and determine if these associations differed by race.

Methods

Population and Design

A prospective cohort study enrolled 372 healthy 3-year-old children in 2001, recruited from the local metropolitan area (Cincinnati, OH) through brochures distributed in area pediatric offices, day care centers, and advertisements placed in community newspapers. Follow-up visits were performed every 4 months with a final visit 4 years later (15). The data collected at the final study visit ($n = 308$ in 2005–2006) were used for these analyses, performed in 2013–2014. The study was approved by the Cincinnati Children's Hospital Medical Center Institutional Review Board, and written informed consent/assent was obtained from the subjects and guardians.

Measures

Physical activity was measured with a triaxial accelerometer (RT3, Stayheallhy, Inc., Monrovia, CA). Participants were instructed to wear the device at the right hip during waking hours for 2 weekdays and 1 weekend day and remove the device for bathing or any activities harmful to the device. A 60 s epoch was used and data were downloaded after each study visit. Wear time was determined by excluding periods of 60 min of zero counts (with the exception of up to 2 consecutive minutes with counts less than 100), a method used and described previously (15,41). Days were defined as starting at 02:00:00, ending at 01:59:59. Days of recording were excluded from analysis in cases of malfunction determined by visual inspection and other errors described previously or if wear time was less than 8 hr (15).

Mean summary physical activity measures for the final study visit (approximately age 7) were calculated as follows: moderate-vigorous physical activity (MVPA, number of minutes ≥ 1,400 counts per minute), light physical activity (LPA, number of minutes > 175 counts per minute and < 1,400 counts per minute), and inactivity (IA, number of minutes ≤ 175 counts per minute) (2).

Age, sex, race, and household income of the participants were reported by the guardians, and weight and height were measured using a Health-O-Meter (Alsip, IL) electronic scale and a custom stadiometer. BMI was calculated (weight/height^2, kg/m^2) and z-scores determined using CDC 2000 growth charts (10). Participants were classified as normal weight (< 85th percentile); overweight (≥85th and <95th percentile) or obese (≥95th percentile).

Blood pressure was measured according to published methods using a standard mercury sphygmomanometer (Baum Desktop Model with V-Lok cuffs) (1) by an examiner certified annually in blood pressure measurement in children. At least three, and up to four, measures were attempted for systolic (Korotkoff phase 1) and diastolic (Korotkoff phase 5) blood pressure. The first measure was discarded, and the mean of the remaining values was used for analysis. If only one valid measure was collected, it was used for analysis. Z-scores and percentiles were assigned based on the Fourth Report (32).

Lipid profile, glucose, and insulin assays were performed on blood drawn following a 12-hr fast and were performed in a National Heart Lung & Blood Institute-Centers for Disease Control & Prevention standardized laboratory. LDL cholesterol concentration was calculated using the Friedewald equation (19). Serum insulin was measured using an radioimmunoassay kit (Linco Research, St. Louis, MO) (30). Standard colorimetric methods were used for measurement of blood glucose (9). Glucose and insulin values for participants with diabetes mellitus type 1 ($n = 1$) were excluded from analyses.

Analysis

Statistical analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC). Means and proportions of all variables were evaluated. Skewed variables were log-transformed and physical activity was adjusted for wear time using the residual method (15,43). An alpha of 0.05 was used to determine significance, and all tests were two-sided. Analysis of covariance and chi-square analyses were used to evaluate differences by sex and race. Pearson correlation coefficients were calculated to assess bivariate associations between physical

activity and cardiovascular risk factors. Household income was evaluated and was not significantly related to any physical activity variable. General linear models were constructed to evaluate the relationship between physical activity measures (independent variables: MVPA, LPA, and inactivity) and cardiovascular risk factors (dependent variables: BMI z-score, systolic blood pressure z-score, diastolic blood pressure z-score, LDL cholesterol, HDL cholesterol, triglyceride, glucose and insulin). Outlier values were inspected and excluded if found to exert undue influence on models. All models were adjusted for age, sex, race, and BMI category. Sex, race and BMI were also evaluated as potential effect modifiers of the relationship between physical activity and each cardiovascular risk factor. Nonsignificant interaction terms were removed from each model. The analyses performed were post hoc therefore an a priori power analysis was not performed.

Results

Three hundred eight participants completed the final study visit at approximately 7 years of age (Table 1). Forty-eight percent were girls and 19% were black. Annual household income was distributed as follows: 9% of families had income < $20,000, 28% $20,000 to $50,000, 32% $50,000 to $75,000, and 31% > $75,000. Eighteen percent of study participants were overweight, 13% were obese, and the remaining 69% were below the 85th percentile for BMI. A higher proportion of black boys and black girls were overweight or obese compared with white boys and white girls ($p = .005$). Differences in cardiovascular risk factors among sex and race groups are reported in Table 1.

In unadjusted analyses, MVPA was negatively correlated with LDL cholesterol (r = −0.19, $p = .005$). LPA was positively correlated with diastolic blood pressure z-score ($r = .14$, $p = .03$) and negatively correlated with triglyceride (r = −0.16, $p = .02$). Inactivity was positively correlated with LDL cholesterol ($r = .14$, $p = .038$) and triglyceride ($r = .19$, $p = .006$). In race-stratified analyses, MVPA was negatively correlated with triglyceride (r = −0.41, $p = .008$), glucose (r = −0.35, $p = .03$), and insulin (r = −0.40, $p = .01$) in black participants but not in white participants. LPA was negatively (r = −0.44, $p = .005$) and inactivity was positively correlated ($r = .53$, $p = .0004$) with triglyceride in black participants but not in white participants.

In multivariable analyses adjusting for age, sex, race, and BMI, greater MVPA remained associated with lower levels of LDL cholesterol (Table 2). We identified an interaction by race in the relationship of MVPA with triglyceride, glucose, and insulin (Figures 1, 2). Greater MVPA was independently associated with lower levels of triglyceride, glucose, and insulin in black participants but not white participants (Table 2). Greater inactivity was associated with greater levels of triglyceride only in black participants (Table 3). Greater LPA was associated with greater diastolic blood pressure z-score ($\beta \pm SE$, 0.01 ± 0.0054 per additional 10 min LPA; $p = .025$) independent of age, sex, race, and BMI. Greater LPA was associated with lower levels of triglyceride in black participants (1% change in mg/dL triglyceride per additional 10 min LPA; $p < .0001$), but not white participants, independent of age, sex, race, and BMI.

An interaction between inactivity and BMI category was also seen for LDL cholesterol, such that more inactivity was associated with higher levels of LDL cholesterol in overweight participants (β ± *SE*, 1 ± 0.43 mg/dL per additional 10 min inactivity; $p = .0077$), but not in normal weight participants (β ± *SE*, 0.09 ± 0.19 mg/dL per additional 10 min inactivity; $p = .63$) after adjustment for age, sex, and race.

Neither MVPA nor LPA nor inactivity was associated with BMI z-score, systolic blood pressure, or HDL cholesterol (Tables 2 and 3; Figure 3).

Discussion

In this study we demonstrated a complex relationship between physical activity and cardiovascular risk factors in 7-year-old children. MVPA and inactivity were associated with triglyceride, glucose, and insulin in black participants but not in white participants. In addition, we found physical activity and inactivity were independently associated with LDL cholesterol across races, but the relationship between LDL cholesterol and inactivity differed by weight status.

Our findings of an association between physical activity and LDL cholesterol build on previous work in this area. This relationship has been found in older children but not in younger children. Jago et al. studied nearly 5,000 sixth-grade students and found fitness was associated with LDL cholesterol and BMI was associated with LDL cholesterol, but an interaction between BMI and fitness was not explored (23). In an earlier study of 6- to 7-year-old children they did not find an association between physical activity and LDL cholesterol (22). Owen et al. studied over 2,000 nine to ten-year-old children and found physical activity was associated with LDL cholesterol, and the strength of this relationship was reduced by adjustment for adiposity, suggesting potential mediation but not necessarily interaction (34). McMurray et al. studied 546 obese children and found no significant relationships between physical activity and lipids, although physical activity was measured by questionnaire only (28). Durant et al. reported physical activity was related to lipids indirectly through fitness and adiposity in 3- to 5-year-old children (13). Our data show the relationship between physical activity and LDL cholesterol is present in children as young as 7 years old. Although we are not aware of other findings of a physical activity-BMI interaction similar to that found in the current study, the existence of an association between physical activity and LDL cholesterol in overweight participants but not normal weight participants fits with prior studies that have demonstrated that fat mass may be an important mediator of exercise effects on lipids (24).

To our knowledge this is the first report of a differential effect of physical activity by race on multiple cardiovascular risk factors in this age group. The findings are strengthened by the consistency of direction of the interaction across multiple variables; reports on this topic in older children and adolescents have not been consistent. In the study by Owen of 2,000 9- to 10-year-old children, associations between physical activity and insulin and triglycerides were found, but the associations were broadly similar in strength in all ethnic groups (34). Using National Health and Nutrition Examination Survey data on 12- to 19-year-olds Bremer et al. found physical activity was associated with triglyceride and insulin in white

participants but not black participants (7). In adults, Lakoski et al. recently reported similar relationships between physical activity and several metabolic risk factors across ethnicities (26). Although our finding of a physical activity-by-race interaction on some cardiovascular risk factors may be novel, it is consistent with other studies focused on exercise, heritability, and cardiovascular risk factors in humans. Rice et al. studied familial aggregation of lipid response to exercise in 214 families and found heritable factors partly determined response, suggesting the interplay between physical activity, race, and lipids may be complex (36). Other studies have also found lipid sensitivity to exercise among black youth but these studies did not include participants of other races or ethnicities for comparison (14,44). It is possible that race differences in visceral adipose tissue and plasma lipoprotein lipase activity that have been demonstrated in adults (12) may offer a potential area to explore for explanation for these differences in exercise effects.

We found that greater LPA was independently associated with lower levels of triglyceride only in black participants, which reinforces our findings of a race interaction related to MVPA. However, we also found that greater LPA was independently associated with greater diastolic blood pressure. We believe these findings highlight the complex nature of light physical activity, a component of PA that is receiving increased attention recently (27). Some studies have repotted beneficial effects of LPA (11), while others have failed to find associations between LPA and health measures (38). Since LPA straddles the intensity spectrum between inactivity and MVPA, PA that is classified as LPA may be near the Inactive threshold (29) or it may be near the MVPA threshold. Our findings of a favorable association with triglyceride but unfavorable with diastolic blood pressure could reflect the possibility that LPA may be of sufficient intensity to favorably affect lipids but may also capture enough inactive time to have a deleterious effect on blood pressure. Since we did not find an association between inactivity and blood pressure, it is also possible that the association of LPA and diastolic blood pressure is spurious.

We did not find a significant association between physical activity (MVPA or inactivity) and blood pressure or BMI. This lack of association is consistent with some previous studies. In a study of 88 children ages 5–11 years, Grund et al. did not demonstrate any differences in activity-related energy expenditure of overweight children compared with normal weight children (20). Brage et al. studied 589 Danish children who were approximately 10-years old and reported no significant independent association between accelerometer-measured physical activity and systolic blood pressure, diastolic blood pressure, or skinfold thickness (6). However, some past studies have reported a relationship between physical activity and BMI/adiposity or blood pressure. Saakslahti et al. studied 155 children ages 4–7 years and found physical activity was associated with BMI in girls, but not boys (37). Ekelund et al. pooled accelerometry data from several large studies and found greater MVPA was significantly associated with smaller waist circumference and lower systolic blood pressure, but sedentary time was not significantly associated with either risk factor (17). However, most of the children in the pooled cohort were older than the children in our analysis. Other investigators have reported on the relationship between physical activity and adiposity or blood pressure in younger ages. Jago el al. studied 3- to 7-year-old children and found physical activity measured by heart rate and direct observation was associated with BMI (21). Butte et al. reported a weak association between physical activity and fat mass, but

participants ranged in age up to 19-years old (8). Recently, Knowles et al. reported an association between accelerometer-measured physical activity and diastolic blood pressure in 5- to 7-year-old children, although the methods differed from our study reported here in that blood pressure was measured automatically rather than manually, and diastolic blood pressure was not age/height/sex-adjusted, potentially explaining the difference in findings (25). Belcher et al. found a relationship between MVPA and BMI and SBP in boys, but the age studied was 12- to 19-years old (4). Stamatakis et al. reported a relationship between TV viewing and SBP, DBP, and clustered cardiovascular risk score in 2,515 school children (40). We surmise from these varied findings that the lipid and metabolic markers that were associated with physical activity in our study are more sensitive to physical activity compared with blood pressure and BMI in a shorter time frame. If this is the case, it is plausible that 7-year-old children have not had long enough exposure to unhealthy levels of physical activity to effect a change in cardiovascular risk factors in the vascular (systolic blood pressure) and adiposity (BMI) categories.

Our findings are strengthened by the use of an objective measure of physical activity (accelerometry), robust methodology for anthropometric and blood pressure measures, and several well-established measures of cardiovascular risk. In addition, the age range in this study was focused in contrast to some larger population-based studies that have a wide age range. Limitations to these conclusions include the cross-sectional analysis, thus preventing causal inferences. The study population was not recruited with the intent of being nationally (or locally) representative, which may limit external validity. Due to demographics of the geographic area, the study enrolled white and black children but not other races/ethnicities. Therefore, we cannot ascertain how the relationship between physical activity and cardiovascular risk factors may vary across other races/ethnicities. In addition, encoding of race in this study relied upon parent report, which may not completely encapsulate such a complex descriptor. Moderate and vigorous physical activity was combined into MVPA to be consistent with published classification cutoffs (2); this combination limits analysis of potential relative effects of vigorous physical activity compared with moderate activity. Although national standards for blood pressure measurement were followed and examiners were trained and certified, having one examiner per encounter as well as the inherent difficulty of measuring diastolic blood pressure in children may result in unmeasured error in the diastolic blood pressure findings. Our study also did not measure cardiorespiratory fitness. Although fitness and physical activity are related, they have been shown to exert independent associations with cardiovascular risk factors (8,16).

Another limitation is the possibility of other unmeasured and unadjusted confounders such as growth history and diet. Past studies have revealed relationships between dietary factors, physical activity, and cardiovascular risk factors. In a longitudinal study of adolescents and adults, Raitakari et al. found that physical activity was related to triglycerides but also to dietary factors (35). In a study of 4- to 10-year-old children with elevated cholesterol, a dietary education intervention affected LDL cholesterol at 3 months compared with control group (39). And in a study of 663 eight to ten-year-old children with elevated LDL, a dietary intervention resulted in improvements to LDL cholesterol (33). However other studies, such as the Woo et al. study of 82 overweight 9- to 12-year-old children, have shown exercise exerting an effect on cardiovascular risk factors independent of diet (45).

In summary, the associations of physical activity with some cardiovascular risk factors in this cohort of 7-year-old children differed by race, with stronger associations in black children. Although there is general consensus that physical activity is beneficial for health in all ages, these findings suggest different cardiovascular risk factors may be more or less sensitive to its effects in different populations. Although these findings should be explored further with longitudinal analyses, they may have implications for the targeting of public health messages and interventions to promote physical activity in children.

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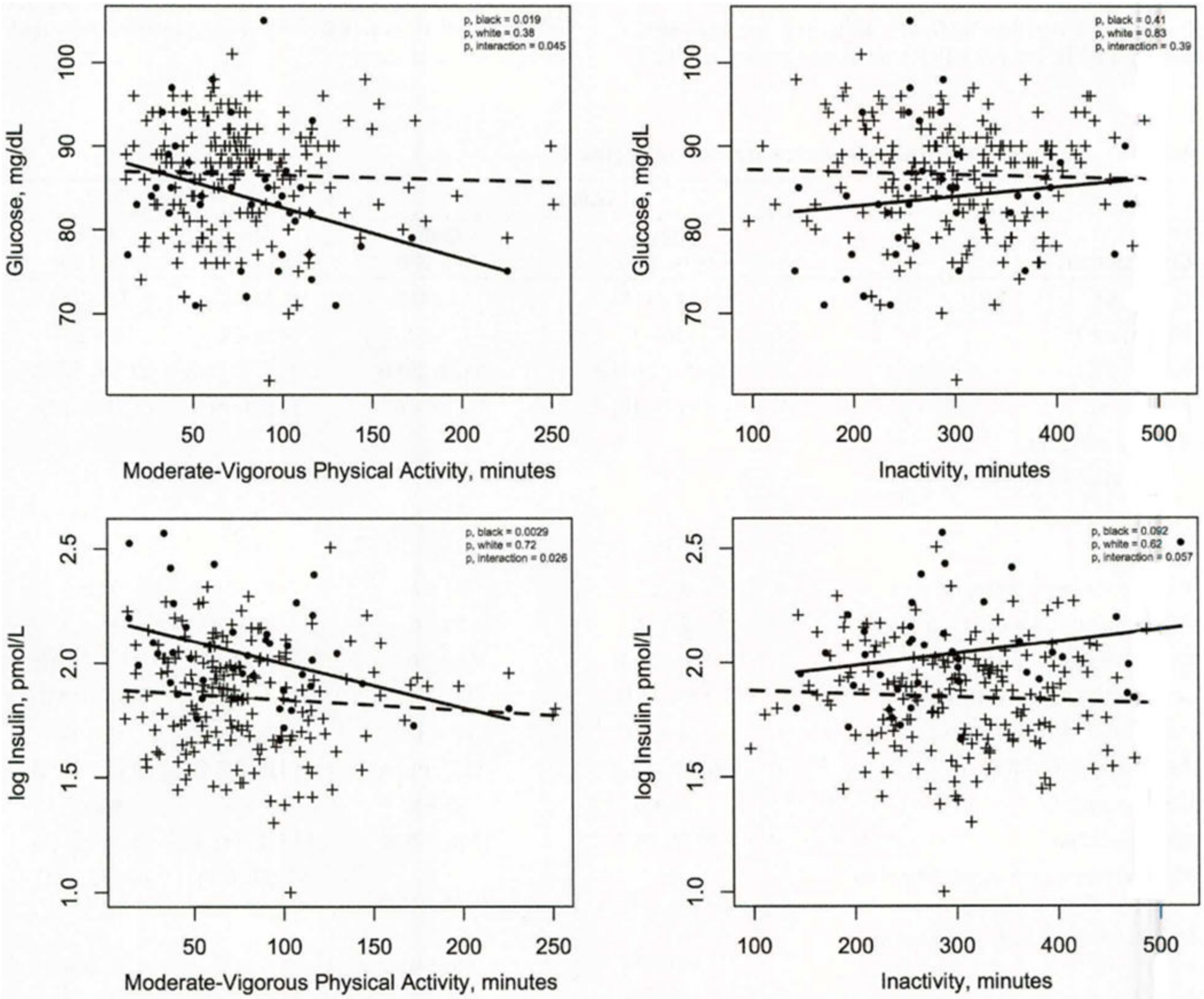

Figure 1—.

Plots of time spent in moderate-vigorous physical activity and inactivity with glucose and insulin by race. Data for black participants are represented by filled circles and solid regression lines; white participants by crosses and dashed regression lines. P values corresponding to each regression line (null hypothesis: slope = 0) and for interaction (null hypothesis: no difference in slope between regression lines) are displayed.

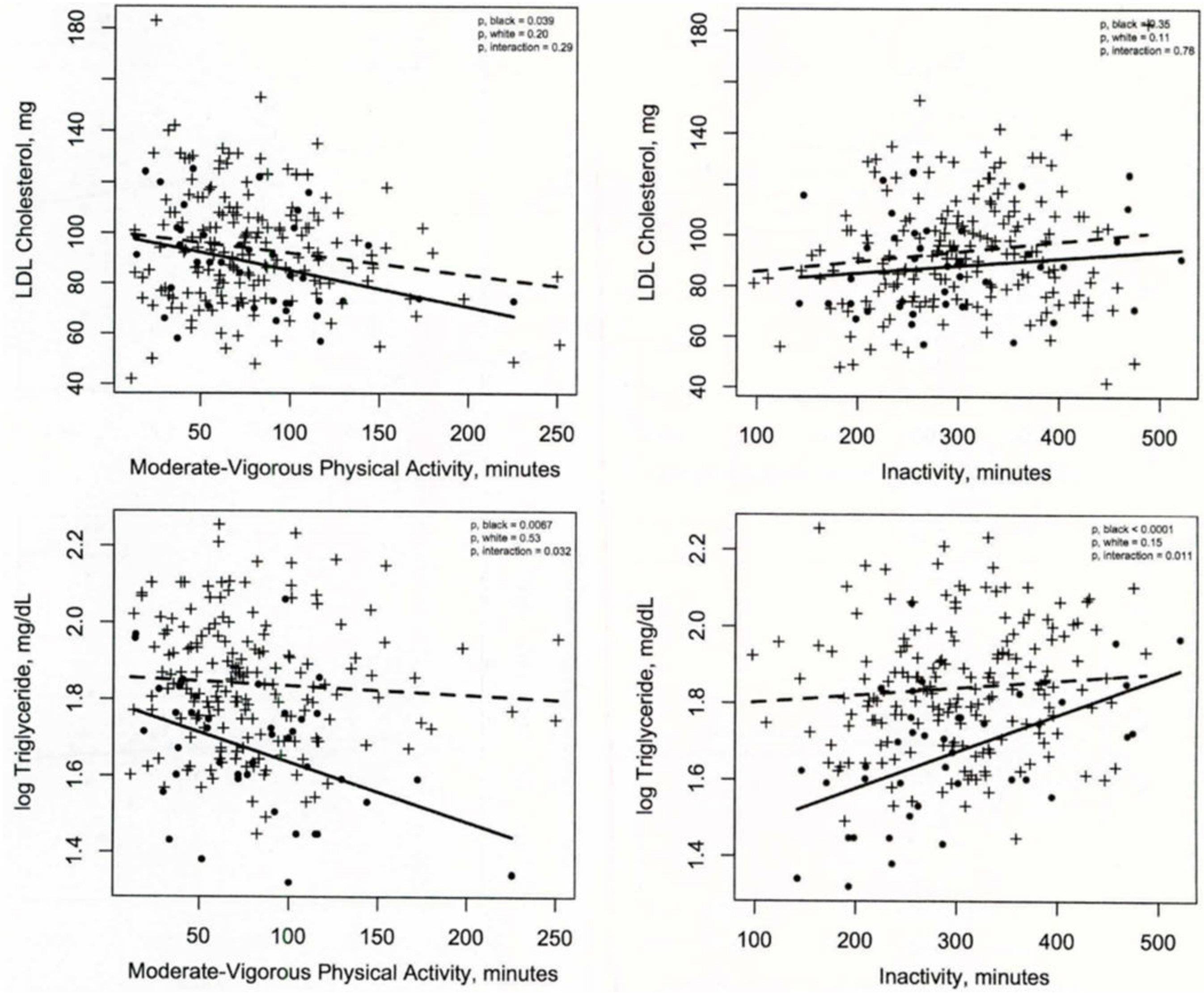

Figure 2—.

Plots of time spent in moderate-vigorous physical activity and inactivity with LDL cholesterol and triglycerides by race. Data for black participants are represented by filled circles and solid regression lines: white participants by crosses and dashed regression lines. P values corresponding to each regression line (null hypothesis: slope = 0) and for interaction (null hypothesis: no difference in slope between regression lines) are displayed.

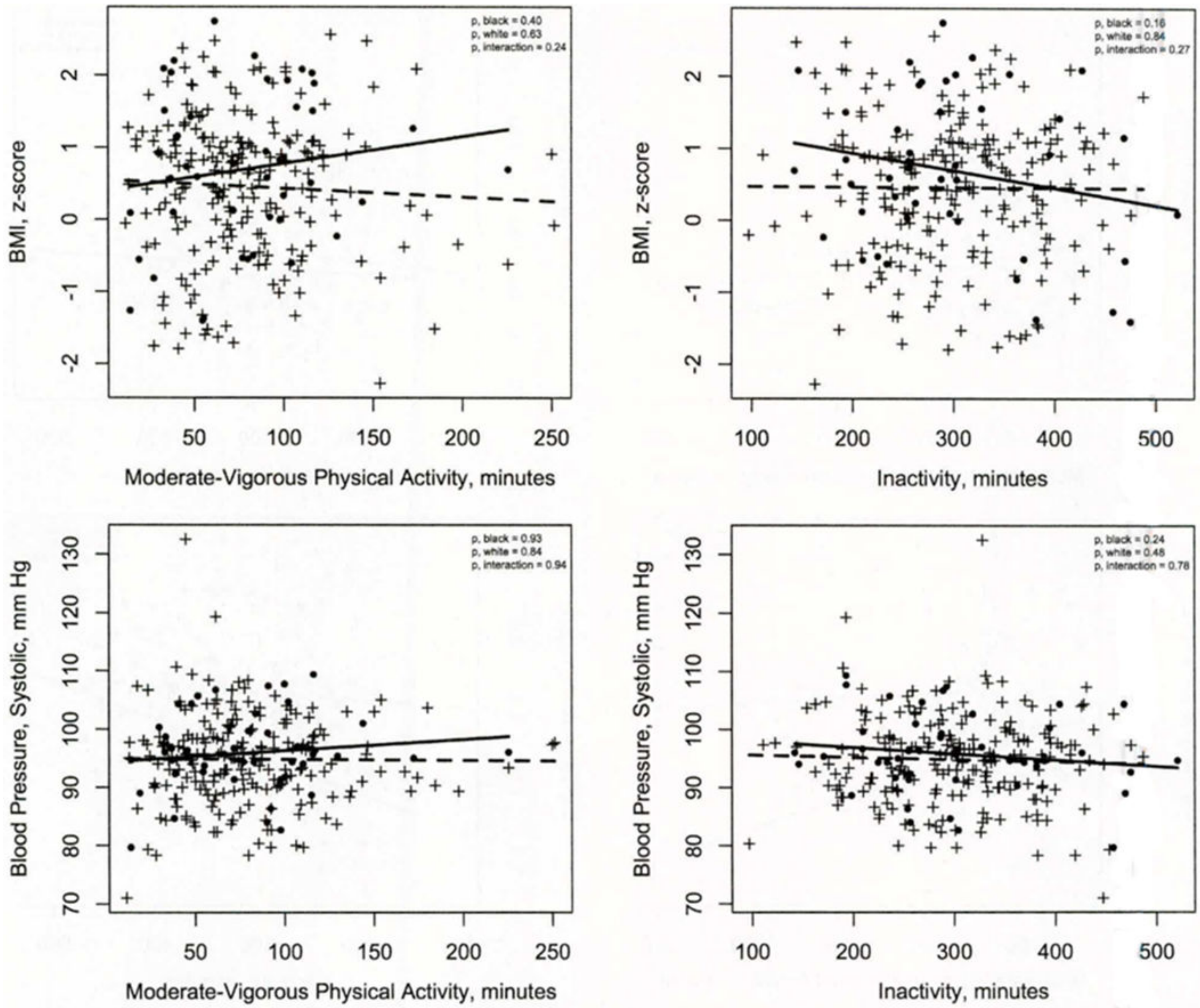

Figure 3—.

Plots of time spent in moderate-vigorous physical activity and inactivity with BMI z-score and systolic blood pressure by race. Data for black participants are represented by filled circles and solid regression lines; white participants by crosses and dashed regression lines. P values corresponding to each regression line (null hypothesis: slope = 0) and for interaction (null hypothesis: no difference in slope between regression lines) are displayed.

Table 1

Participant Characteristics by Sex and Race

	White		Black	
Characteristics	**Boys (*n* = 136)**	**Girls (*n* = 114)**	**Boys (*n* = 23)**	**Girls (*n* = 35)**
Age, years	7.4 ± 0.3	7.4 ± 0.3	7.3 ± 0.3	7.4 ± 0.3
Height, cm	126 ± 6	125 ± 5	126 ± 6	126 ± 7
Weight, kg	26 [23, 29] AB	26 [23, 29] B	27 [23, 32] AB	27 [24, 36] A
BMI, kg/m2	16 [15, 18]	17 [15, 18]	17 [16, 19]	17 [15, 22]
BMI classification *	16 [15, 18]	17 [15, 18]	17 [16, 19]	17 [15, 22]
normal/underweight, %	71	74	61	51
overweight, %	17	18	26	14
obese, %	12	9	13	34
Blood pressure, systolic, mm Hg	95 ± 7	94 ± 8	98 ± 7	95 ± 6
Blood pressure, diastolic, mm Hg	55 ± 6	55 ± 6	55 ± 6	55 ± 5
Cholesterol, total, mg/dL	158 ± 24 B	168 ± 26 A	157 ± 23 AB	158 ± 21 AB
Low-density lipoprotein, mg/dL	89 ± 21 B	99 ± 22 A	90 ± 17 AB	90 ± 20 AB
High-density lipoprotein, mg/dL	54 ± 10	53 ± 11	58 ± 9	56 ± 10
Triglycerides, mg/dL	66 [49, 86] AB	73 [57, 96] A	45 [28, 57] C	57 [42, 70] B
Glucose, mg/dL	88 ± 6	85 ± 6	84 ± 9	85 ± 7
Insulin, μIU/mL	10 [7, 13] B	13 [6, 12] B	19 [14. 14] A	16 [12, 21] A
Physical Activity, moderate-vigorous intensity, minutes per day	80 [56, 112] A	66 [45, 86] B	67 [37, 111] AB	83 [42, 101] AB
Physical Activity, light intensity, min/day	369 ± 59	376 ± 61	355 ± 77	391 ± 60
Inactivity, min/day	294 ± 79	309 ± 74	316 ± 109	283 ± 75

Note. Presented as mean ± *SD* if normal distribution, median [interquartile range] for skewed distribution.

*Chi-square $p < .01$. ANOVA differences denoted by different letters adjacent to columns.

Table 2

Models Exploring Moderate-Vigorous Physical Activity (MVPA, Min) as Predictor of Cardiovascular Risk Factors

Factors	Overall (β ± SE)	White Participants (β ± SE)	Black Participants (β ± SE)
BMI, z-score	not significant		
Blood pressure, systolic, z-score	not significant		
Blood pressure, diastolic, z-score	not significant		
Low-density lipoprotein (LDL) cholesterol, mg/dL	−0.8* ± 0.34		
High-density lipoprotein (HDL) cholesterol, mg/dL	not significant		
Triglycerides[a], mg/dL	differs by race[b]	−0.002 ± 0.003	−0.02** ± 0.0055
Glucose, mg/dL	differs by race[b]	−0.1 ± 0.12	−0.6* ± 0.26
Insulin[a], μIU/mL	differs by race[b]	−0.001 ± 0.0041	−0.02** ± 0.0066

Note. BMI z-score model adjusted for age, sex, and race. Blood pressure and HDL models adjusted for age, sex, race, and BMI category (normal, overweight, obese). Triglyceride, glucose, and insulin models adjusted for age, sex, and BMI category, and stratified by race. MVPA: moderate-vigorous physical activity. All beta estimates relate to 10 min of MVPA.

[a]Variable log-transformed

[b]Interaction $p < .05$

*$p < .05$ and $\geq .01$

**$p < .01$ and $\geq .001$

Table 3

Models Exploring Inactivity (Min) as Predictor of Cardiovascular Risk Factors

Factors	Overall (β ± SE)	White Participants (β ± SE)	Black Participants (β ± SE)
BMI, z-score	not significant		
Blood pressure, systolic, z-score	not significant		
Blood pressure, diastolic, z-score	not significant		
High-density lipoprotein (HDL), mg/dL	not significant		
Triglycerides[a], mg/dL	differs by race[b]	0.002 ± 0.0016	0.01[***] ± 0.0023
Glucose, mg/dL		−0.01 ± 0.064	0.1 ± 0.14
Insulin[a], μIU/mL		−0.001 ± 0.002	0.006 ± 0.0035

Note. BMI z-score model adjusted for age, sex, and race. Blood pressure and HDL models adjusted for age, sex, race, and BMI category (normal, overweight, obese). Triglyceride, glucose, and insulin models adjusted for age, sex, and BMI category, and stratified by race. All beta estimates relate to 10 min of inactivity.

[a]Variable log-transformed.

[b]Interaction $p < .05$

[*] $p < .05$ and ≥ .01

[**] $p < 0.01$ and ≥ .001

[***] $p < .001$