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# A Pilot Study of Cardiorespiratory Fitness, Adiposity, and Cardiometabolic Health in Youth With Overweight and Obesity

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## Abstract

**Objective—**To conduct a preliminary assessment of the relationships between cardiorespiratory fitness, adiposity, and cardiometabolic health using gold standard measures in diverse youth ranging from overweight to severe obesity.

**Methods—**Twenty of 30 participants (mean [SD]; age 13.2 [1.8] y, 55% female, 45% African American) met the criteria for $VO_2$peak during a graded cycle ergometer test to volitional fatigue. The body composition was measured by dual-energy X-ray absorptiometry (percentage of body fat, fat mass index, and fat-free mass) and magnetic resonance imaging (abdominal visceral and subcutaneous [SAT] adipose tissue). The $VO_2$peak was expressed relative to fat-free mass. Fasting lipid levels, glycemic biomarkers, and vital signs were examined individually and used in a composite cardiometabolic risk score. Accelerometer-measured physical activity and sedentary time were included as covariates.

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**Results—**$VO_2$peak was negatively associated with abdominal SAT ($r = -.49$, $P < .05$), but not visceral adipose tissue or markers of cardiometabolic health. The association between SAT and $VO_2$peak was partly explained by habitual sedentary time.

**Conclusions—**We demonstrated a significant negative association between cardiorespiratory fitness and SAT in a diverse group of high-risk youth. The inclusion of rigorous, laboratory-based measures and youth with severe obesity extends the previous work in pediatric populations.

## Keywords

adipose tissue; body composition; exercise physiology; sedentary behavior; severe obesity

Maintaining high cardiorespiratory fitness has been shown to be protective against the development of type 2 diabetes and cardiovascular disease, independent of body weight (BW [1,30]). In adults, high fitness is associated with reduced mortality, even when controlling for other risk factors for cardiometabolic disease, such as whole-body adiposity (6,20). However, individuals with severe obesity are underrepresented in clinical exercise studies, often due to orthopedic or other safety concerns (eg, increased shortness of breath), hesitation to push participants to maximal effort, or the lack of a tailored exercise testing protocol design that facilitates maximal effort. The American College of Sports Medicine guidelines for exercise testing and prescription (2) in individuals with obesity do not include a distinction between levels of obesity (ie, mild, moderate, severe), despite differences in physical and pulmonary function across weight classes (17,22,38,43). The lack of tailored guidelines and adapted protocols limits our understanding of fitness in the context of severe obesity. Of particular interest is whether specific fat depots may negatively influence fitness in this population. In one study of adults, the degree of total and abdominal adiposity is negatively associated with the estimated $VO_2$max, independent of the body mass index (BMI [35]).Contrarily, previous reviews have suggested that there is no relation between body fat and fitness (18), citing that individuals with obesity also have greater muscle mass (9,13). The association between BMI and relative $VO_2$peak (mL/kg/min) is confounded by the fact that both variables incorporate total BW (18,39). Less rigorous work is available in children, but similar concerns over measurement and how it relates to adequate risk assessment are present (47).

Adjustment of $VO_2$peak for total BW is particularly inappropriate in youth (3,46), as the association between BW and $VO_2$peak across development is not linear (4). An adjustment of $VO_2$peak for fat-free mass (FFM) rather than total BW allows for a truer estimate of cardiorespiratory fitness, as FFM is a primary determinant of $VO_2$peak, regardless of age (3,4,46). Studies in youth show a .87 to .94 correlation coefficient ($r$) between FFM and $VO_2$peak (L/min) (4). Nevertheless, studies in this area generally lack gold standard measures, such as dual-energy X-ray absorptiometry (DXA) and magnetic resonance imaging (MRI) for body composition and laboratory-based measures of $VO_2$peak. Many previous reports in youth rely heavily on field tests such as the 20-m shuttle run test with equations to estimate $VO_2$peak, as well as skinfold estimates of total body adiposity and lean mass (47). Collectively, the methodological limitations of the available studies in youth demonstrate a gap in understanding the associations between cardiorespiratory fitness, excess total and regional adiposity, and other cardiometabolic risk factors. Therefore, we

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recruited adolescent participants ranging from overweight to severe obesity, with the primary aim to examine the cross-sectional association between $VO_2$peak and clinical biomarkers of chronic disease risk. We hypothesized that lower $VO_2$peak (adjusted for FFM) would be associated with higher body fat and poorer cardiometabolic health.

Sex differences in the relationships between fitness and adiposity represent an additional knowledge gap. Previous epidemiological studies have demonstrated that adolescent girls tend to have lower physical activity levels and higher sedentary time compared with boys (10). Following the onset of puberty, girls also tend to have higher levels of total body fat than boys (40,41). Combined, an inactive lifestyle and higher body fat potentially put girls at greater risk for poorer fitness and cardiometabolic health compared with boys (29). The divergence of fitness between boys and girls is evident even in the prepubertal stage of development, with a ~10% difference in the $VO_2$peak (4). This sex difference has been shown to increase to ~40% in postpubertal adolescents (4). Therefore, we examined sex differences in the association between the $VO_2$peak and measures of body fat and cardiometabolic health across the pubertal transition. We anticipated that these relationships would be stronger in girls, as a traditionally higher risk group. With known differences in body composition between white and African American individuals, we also conducted an exploratory analysis by racial background. As African Americans tend to have higher FFM and lower visceral adipose tissue (VAT) for the same BW (9,24), we hypothesized that they would have higher fitness levels than white adolescents and would be less susceptible to any effects of higher body fat.

## Methods

### Study Design

Study information was provided to potential participants at an orientation visit for a larger, longitudinal cohort study, during which, parents signed informed consent and children signed written assent to participate in the longitudinal cohort study. A subsample of the participants, ages 10–16 years (inclusive) with a BMI ≥ the 85th age- and sex-specific percentile, based on parent-reported height and weight at the initial phone screen, were offered enrollment in this fitness-related ancillary study.

If interested, the parents and children signed an additional informed consent and written assent, respectively, for the ancillary study procedures at their baseline clinic visit. During this initial clinic visit, the participants underwent a fasting blood draw and assessment of vital signs, anthropometrics to verify BMI percentile and body composition, and self-reported pubertal development. The participants also received a brief introduction to the cycle ergometer test with the exercise-testing staff. After completion of the screening procedures at the initial clinic visit, additional eligibility criteria were assessed, as follows: (1) the ability to understand instructions and complete all study procedures, (2) meeting physical (height and weight) restrictions for the cycle ergometer, (3) not anemic, (4) not pregnant, (5) not on a restrictive diet, (6) no contraindications to exercise testing (as defined by the American College of Sports Medicine, [2]), and (7) no significant physical or mental disabilities. The eligible participants returned 7 to 21 days later for an additional visit, where cardiorespiratory fitness testing and the remaining questionnaires and behavioral tasks were

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completed. Recruitment continued until the target sample size of 30 participants was enrolled and completed the study procedures. All procedures were approved by the Pennington Biomedical Research Center Institutional Review Board.

## Cardiometabolic Health Markers

The participants arrived for their initial clinic visit after an overnight fast (12 h), confirmed by parental report. Height (cm), weight (kg), and waist circumference (cm) were measured by trained staff according to standard clinical procedures. These values were used to calculate the BMI and age- and sex-specific BMI percentiles (11). Adolescents with a BMI percentile ≥ 85 but <95 were considered overweight, and those with a BMI percentile ≥ 95 were considered to have obesity. Severe obesity was defined as ≥120% of the 95th BMI percentile for age and sex. Resting blood pressure (BP, mm Hg) was assessed manually on a standard sphygmomanometer (Welch Allyn, Skaneateles Falls, NY), following standardized clinical procedures. Resting heart rate (HR, beats per minute) was measured by palpation. Both BP and HR procedures took place after 5 minutes of rest in a quiet room without distraction.

A fasting blood sample was taken by a phlebotomist following standardized clinical procedures. Serum concentrations of glucose, triglycerides, low-density lipoprotein cholesterol, and high-density lipoprotein cholesterol (HDL-C) were obtained from a DXC600 manufactured by Beckman Coulter (Brea, CA). Insulin was assayed on the Siemens Immulite 2000 (Siemens, Tarrytown, NY). Insulin resistance was quantified using the homeostatic model assessment. Serum high-sensitivity C-reactive protein (hsCRP) levels were determined by immunoassay with chemiluminescent detection, run on an Immulite 2000 (Siemens). Hemoglobin and hematocrit were assessed with a complete blood cell count on a Unicel DxH 800, manufactured by Beckman Coulter, to determine the presence of anemia. The medical investigator reviewed a parent-reported medical history for the presence of any contraindications to exercise testing.

A continuous cardiometabolic risk score was calculated using the Eisenmann method (14): the BMI, mean arterial pressure (mean arterial pressure = [(2 × Diastolic BP) + Systolic BP]/3, HDL-C), fasting blood glucose, and triglycerides were regressed on age, sex, and race, and the standardized residuals were summed (HDL-C multiplied by −1).

## Body Composition

Body composition was measured with both whole-body DXA and abdominal MRI. The participants completed their DXA scan on a General Electric iDXA scanner (GE Medical Systems, Milwaukee, WI) while supine on the table in a hospital gown, with all metal removed. The scans were automatically analyzed with Encore (version 16.6; GE Medical Systems) for Windows. The total fat mass (FM, kg) was extracted from the data set and used to calculate the percentage of body fat (%BF; FM divided by BW × 100). The FM index ($kg/m^2$) was calculated as FM (kg) divided by height (m) squared. The total FFM (kg) was calculated as BW – FM.

Abdominal VAT and subcutaneous adipose tissue (SAT) were assessed by water-fat MRI on a GE Discovery 750 w 3.0 Tesla magnet (GE Medical Systems). The IDEAL-IQ pulse

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sequence was used to generate water only, fat only, in-phase, and out-of-phase images in a single acquisition, with a 20-second breath-hold (acquisition parameters—field of view: 46, phase field of view: 0.9, slice thickness: 10 mm, gap: 0, frequency: 224, phase: 160, repetition time: 7.8, echo time: Min Full (1.1), number of excitations: 0.5). The images were analyzed using the ANALYZE (CNSoftware, Rochester, MN) software package. The L4/L5 disc space was used as the anatomical point of reference for analysis. The slice at L4/L5, 2 slices below L4/L5, and 5 to 6 slices above L4/L5 were analyzed. The slices analyzed above L4/L5 were determined based on the location of the dome of the diaphragm (analysis was stopped at the dome). VAT and SAT traces were drawn manually on every fifth slice by one trained technician, and additional calculations were used to determine the VAT and SAT volume (L) and mass (kg).

## Cardiorespiratory Fitness

Cardiorespiratory fitness ($VO_2$peak) was determined with a graded cycle ergometer test with the use of standard open-circuit metabolic cart (TrueOne 2400; ParvoMedics, Sandy, UT) until volitional fatigue. This protocol was designed to measure the steady-state responses to exercise at multiple submaximal stages leading up to a maximum workload. Prior to beginning the test, the participants underwent a 5-minute warm-up on the cycle ergometer to ensure comfortable positioning on the bike and practice pedaling at the appropriate cadence (60 revolutions per min).

The metabolic cart measurement began with 2 minutes of rest in a seated position on the cycle ergometer. The participants then commenced with an unloaded stage, and then the workload increased in 35-W increments until at least 2 submaximal (loaded) steady state measurements were obtained. These initial stages were 3 minutes in length. Closer to the maximum, the workload increased in smaller, 15-W increments so that there were no abrupt increases in workload, just a gradual rise in work intensity to fatigue. These stages lasted 1 minute. The HR was monitored by a Polar sensor (Polar Electro Inc, Bethpage, NY) and Zephyr Bio-Harness (Medtronic, Boulder, CO) worn around the chest. The blood pressure was taken manually with a sphygmomanometer at the end of each 3-minute stage and at every other 1-minute stage thereafter. Additional electrocardiogram monitoring was included on a case-by-case basis per recommendation from the medical investigator. The participants provided ratings of perceived exertion (RPE) on the Borg 6 to 20 scale at each stage (8). The test concluded with a monitored active cool-down phase.

The participants who met 2 or more of the following criteria were included in the analysis of $VO_2$peak, as follows: (1) plateau in $VO_2$ with a change in $VO_2$ of <2.1 mL/kg/min with increasing exercise intensity at near maximal intensity, (2) peak respiratory exchange ratio ≥ 1.00 (12,36), (3) peak HR ≥ 90% of the predicted maximum, or (4) RPE ≥ 19. We have expressed $VO_2$peak relative to total BW (mL/kg BW/min) and relative to total FFM (mL/kg FFM/min). As a secondary fitness variable, delta efficiency (percentage) was calculated as the reciprocal of the slope for the line joining the points on a plot for energy expenditure (kcal/min) versus work rate (Watts × 0.014 = kcal/min). Energy expenditure was calculated from the measures of $VCO_2$ and $VO_2$ obtained from the metabolic cart using standard

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stoichiometric equations (7). All participants with at least 3 steady state stages were included in the analysis of delta efficiency.

### Habitual Physical Activity and Sedentary Time

Physical activity and sedentary time were measured by accelerometer (ActiGraph GT3X+; Ft. Walton Beach, FL). The participants were instructed to wear the accelerometer on an elasticized belt on the left midaxillary line 24 hours per day for at least 7 days (plus an initial familiarization day and the morning of the final day), including 2 weekend days. A 7-day monitoring protocol provides reliable estimates of children's free-living physical activity behavior (45). The nocturnal sleep period was identified based on a fully automated, validated algorithm (5,44). The minimal amount of accelerometer data considered acceptable was 4 days, with at least 10 hours of awake wear time per day (excluding the sleep period), including at least 1 weekend day. The cut points were assigned based on Evenson et al (16), with 0 to 25 counts per 15-second epoch (CPE) classified as sedentary, 26 to 573 CPE as light, 574 to 1002 CPE as moderate, and ≥1003 CPE as vigorous.

### Statistical Analysis

This ancillary study was not specifically powered to test the hypothesis that fitness is negatively associated with body fat or cardiometabolic health. Therefore, the findings should be interpreted with caution. The data presented here will generate sample-size estimates for larger investigations.

The participant characteristics were generated by descriptive statistical analysis (frequencies, means, SDs, and ranges), and differences by sex and race were examined with independent samples *t* tests. Two participants had excessive breathing motion during MRI, limiting the analysis of VAT and SAT. We used Pearson correlations to test the associations between body composition by DXA (FM index, total %BF) and MRI (VAT and SAT) and $VO_2$peak (mL/kg BW/min, mL/kg FFM/min) across the full sample, and by sex and race. We also report partial correlations on the full sample, controlling for age, sex, and race. Similar analytic strategies were used for the cardiometabolic biomarkers, including the following: (1) systolic and diastolic BP, (2) homeostatic model assessment, (3) low-density lipoprotein cholesterol, (4) HDL-C, (5) triglycerides, (6) hsCRP, and (7) the continuous cardiometabolic risk score. In addition, we tested the influence of habitual physical activity (light, moderate, and vigorous) and sedentary time on $VO_2$peak, body composition, and cardiometabolic risk factors. Four participants had insufficient accelerometry data, limiting this exploratory analysis.

The data were collected and managed using Research Electronic Data Capture (REDCap) tools (21). The data were analyzed in SPSS (version 24; IBM SPSS Statistics, Armonk, NY). The results were considered significant at $P < .05$.

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# Results

## Participant Characteristics

Twenty participants met 2 or more of the criteria for $VO_2$peak. All 20 achieved a respiratory exchange ratio ≥ 1.0 (mean = 1.07, range = 1.00–1.18). Twelve participants achieved a HR ≥ 90% predicted maximum (mean = 184 beats/min, range = 154–205 beats/min). Thirteen participants achieved an RPE ≥ 19 (mean = 18.2, range = 13–20). Eleven participants achieved a plateau in $VO_2$, indicating maximal effort. One participant stopped the test early and did not have enough data for a calculation of delta efficiency (n = 29).

The participants were an average of 13 years of age and nearly evenly split between white and African American, with 80% having obesity or severe obesity (Table 1). These variables did not differ by sex (n = 11 female and n = 9 male). All participants were considered peripubertal based on self-reported Tanner staging, which was collinear with age among boys and girls (both $r > .80$, $P < .01$).

The means and distributions by sex and race for the body composition and cardiorespiratory fitness variables are presented in Table 2. There were no sex differences in body composition. As expected, the boys had significantly higher cardiorespiratory fitness levels, regardless of whether the $VO_2$peak was expressed per kg body weight or per kg FFM (both $P < .05$). With the exception of VAT being lower in African American adolescents ($P < .05$), there were no other significant race differences in body composition or $VO_2$peak. Additional descriptive information on cardiometabolic health markers can be found in Supplementary Table S1 (available online). Descriptive information regarding physical activity and sedentary behavior can be found in Supplementary Table S2 (available online).

## Correlations Between Cardiorespiratory Fitness, Body Composition, and Cardiometabolic Health

Correlations between fitness, body composition, and cardiometabolic health markers are reported in Table 3. $VO_2$peak (mL/kg FFM/min) was negatively associated with SAT (kg), such that those with poorer fitness levels had higher abdominal adiposity. $VO_2$peak expressed relative to total BW (mL/kg BW/min) was negatively associated with the FM index (kg/m$^2$), %BF, SAT (kg), and resting diastolic BP (mm Hg) (all $P < .05$). As a secondary marker of fitness, delta efficiency was positively associated with %BF, such that the participants who were more efficient (ie, required less energy to generate the same amount of work during exercise) had higher adiposity. Efficiency was also positively associated with hsCRP levels.

Subgroup analyses by sex and race are summarized in Supplementary Table S3 (available online). In white adolescents only (n = 11), the $VO_2$peak (mL/kg FFM/min) was negatively associated with FM index, %BF, and SAT.

## Covariate Analysis

Partial correlations between $VO_2$peak (mL/kg FFM/min) or delta efficiency and body composition and cardiometabolic health measures, controlling for age, sex, and race, are

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reported in Table 4. With limited degrees of freedom, no associations for $VO_2$peak (mL/kg FFM/min) remained significant after the adjustment. Delta efficiency was positively associated with FM index, %BF, and hsCRP in partial correlations, such that the participants who were more metabolically efficient had higher adiposity and inflammation.

Objectively measured physical activity of any intensity (light, moderate, or vigorous) was not associated with any of the fitness, body composition, or cardiometabolic health measures. The amount of time spent sedentary (average minute per day) was negatively associated with $VO_2$peak (mL/kg FFM/min; $r = -.52$ [−.81 to −.03], $P = .04$). Sedentary time was positively associated with SAT ($r = .48$ [.11–.74], $P = .02$). The association between $VO_2$peak and SAT was no longer significant when controlling for sedentary time ($r = -.41$ [−0.75 to 0.11], $P = .14$).

## Discussion

Individuals with severe obesity are particularly underrepresented in exercise-based studies, limiting our understanding of the associations between cardiorespiratory fitness and cardiometabolic health in individuals with high levels of adiposity. We conducted a cross-sectional analysis of 20 youth, ranging from overweight to severe obesity, with laboratory-based measures of cardiorespiratory fitness, body composition, and cardiometabolic risk factors. In this pilot study, we found that SAT showed the strongest inverse association with $VO_2$peak, which may be partly explained by habitual sedentary time.

Youth with severe obesity represent a notably high-risk group for lifelong cardiometabolic disease (17,37). As weight tends to track from adolescence to adulthood (34), youth with obesity are at an increased risk for developing comorbidities, such as type 2 diabetes and cardiovascular disease (25,33). Earlier onset obesity predisposes youth to an even longer duration of disease burden. Exercise is known to promote changes in cardiometabolic health markers beyond weight loss (26,32). Cardiorespiratory fitness is a strong biomarker for regular exercise engagement and a relatively noninvasive measure. We demonstrated a 67% success rate for reaching peak criteria with our cycle ergometer protocol in this population. Current reference values for $VO_2$peak in children would place our participants below the second percentile for their age and sex (15). However, these reference curves are based on field tests of fitness and estimate $VO_2$peak with predictive equations, expressed relative to total BW (mL/kg/min) rather than FFM. Therefore, they are not the best comparison for our population. Regardless, we do assume that the $VO_2$peak levels in our participants could be improved. Engagement in regular exercise can positively impact both cardiorespiratory fitness and cardiometabolic health in individuals with obesity (27,29), with a potential role for body fat in mediating the resulting health changes.

While the insulin-sensitizing effects of regular exercise appear to be predominantly regulated in skeletal muscle (23), adipose tissue has a role in the development of insulin resistance and is known to be responsive to exercise (31,26). The majority of the research focus is typically placed on VAT (19,48), given the close proximity and hormonal signaling between VAT and key organs involved in glucose homeostasis. However, SAT typically composes a larger percentage of the adipose tissue present in the abdominal region in youth

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(40) and, therefore, may have a greater potential to affect metabolic health relative to VAT. In our study, SAT mass was approximately 10 times greater than VAT mass. High levels of SAT and adipocyte hypertrophy in obesity promote inflammation, which may contribute to reduced cardiorespiratory fitness and the development of cardiometabolic disease. Previous studies have shown that SAT is positively associated with insulin resistance in adolescents with obesity (42). Given that habitual sedentary time was also associated with SAT, these preliminary cross-sectional findings suggest that regular exercise in place of sedentary time could potentially exert independent effects on each of these markers, but further research is needed to understand how they relate to one another over the longer term.

In our sample, the $VO_2$peak (mL/kg FFM/min) was 19.8% higher in boys compared with girls. Larger amounts of muscle mass are typically an explanatory factor for sex differences in fitness across puberty (4), but we showed no sex differences in FFM measured by DXA. In addition, adjustment of fitness for FFM should eliminate this effect. Other factors shown to contribute to sex differences in fitness in the postpubertal period include stroke volume, maximal arteriovenous oxygen difference, and hemoglobin concentration (ie, oxygen carrying capacity) (4). Hemoglobin was not significantly different between boys and girls in our sample ($P = .38$). We do not have additional cardiovascular parameters in our cohort, but these factors do warrant additional investigations in youth with severe obesity. Future studies should also explore the contribution of sex hormones (ie, testosterone and estrogen) and other circulating growth-signaling molecules (ie, growth hormone, insulin-like growth factor) to sex differences in the association between fitness and cardiometabolic risk factors in youth.

Our ability to explore race differences is limited by the pilot nature of this study, but we did observe that white adolescents had significant associations for $VO_2$peak (mL/kg FFM/min) with body fat indices (ie, FM index, %BF, SAT). The effect sizes were smaller and nonsignificant among African American adolescents. We also did not find significant differences between groups in FFM or $VO_2$peak, as hypothesized. Future studies could clarify these differences further with larger samples and also examine other factors beyond demographics that could be influencing these relationships. One study showed that adolescents with obesity with a reduced capacity to expand SAT depots were more susceptible to inflammation and insulin resistance (28). Future studies could examine the genetic differences in SAT expandability between racial groups, and whether this is a factor in $VO_2$peak. In addition, although there was an association between delta efficiency and %BF in the full study sample, no group differences were found in metabolic efficiency that could explain the differential associations with $VO_2$peak in our limited sample. Of note, higher levels of efficiency were associated with greater adiposity in this population. This finding may have implications for future exercise-based programs in youth with severe obesity, such that higher doses (increased work) may be required to generate the same energy expenditure for the exercise prescription.

The cross-sectional nature of the analyses limits our ability to assign directionality in our associations, and we cannot determine whether low $VO_2$peak or high SAT appeared first in these adolescents. We also acknowledge the small sample sizes and limited degrees of freedom in subgroup and partial correlation analyses, and caution against an

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overinterpretation of any subgroup findings. Strengths include gold standard measures of body composition and $VO_2$peak, to extend previous research beyond the field fitness test and skinfold measures used in previous studies. This allowed for the in-depth assessment of compartmental body composition, rather than estimated total body fat, as well as true $VO_2$peak and metabolic efficiency from gas exchange measurement. The inclusion of youth with severe obesity is an important contribution to the literature and should provoke further investigation of exercise physiology in this understudied population.

In conclusion, the findings of this pilot study suggest that cardiorespiratory fitness may be negatively associated with SAT in adolescents ranging from overweight to severe obesity and may be partly explained by habitual sedentary activity. This work supports the need for effective childhood obesity management strategies that incorporate regular exercise in place of sedentary time. Future studies should examine the potential deleterious effects of combined high-central adiposity and low fitness on metabolic health over time, particularly through the transition from adolescence to adulthood.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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**Table 1**

Participant Characteristics

| Characteristic | Boys (n = 9) Mean (SD) | Girls (n = 11) Mean (SD) | All (N = 20) Mean (SD) |
|---|---|---|---|
| Age, y | 13.4 (1.7) | 13.0 (1.8) | 13.2 (1.8) |
| | n (%) | n (%) | n (%) |
| Race | | | |
| White | 5 (56%) | 6 (55%) | 11 (55%) |
| African American | 4 (44%) | 5 (45%) | 9 (45%) |
| Weight status | | | |
| Overweight | 2 (22%) | 2 (18%) | 4 (20%) |
| Obesity, not severe | 4 (44%) | 7 (64%) | 11 (55%) |
| Obesity, severe | 3 (33%) | 2 (18%) | 5 (25%) |

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**Table 2**

Descriptive Statistics (Mean [95% CI]) for Body Composition and Cardiorespiratory Fitness by Sex and Race

| Measure | Boys (n = 9) | Girls (n = 11) | White (n = 11) | African American (n = 9) |
|---|---|---|---|---|
| FFM, kg | 48.4 (42.4–54.4) | 43.5 (37.1–49.9) | 45.7 (38.9–52.5) | 45.7 (39.9–51.5) |
| Fat mass index, kg/m$^2$ | 10.6 (8.0–13.2) | 12.2 (10.4–14.0) | 11.7 (10.5–12.9) | 11.1 (8.1–14.1) |
| %BF | 36.2 (32.0–40.4) | 41.2 (37.6–44.8) | 40.2 (36.8–43.6) | 37.4 (32.2–42.6) |
| VAT, kg[a] | 0.95 (0.61–1.29) | 0.82 (0.62–1.02) | 1.04** (0.86–1.22) | 0.64 (0.34–0.94) |
| SAT, kg[a] | 7.51 (4.87–10.15) | 9.50 (7.64–11.36) | 8.49 (6.89–10.09) | 8.81 (5.43–12.19) |
| $VO_2$peak, mL/kg BW/min | 28.7* (24.7–32.7) | 21.8 (19.0–24.6) | 25.6 (21.2–30.0) | 24.1 (20.5–27.7) |
| $VO_2$peak, mL/kg FFM/min | 47.1* (42.1–52.1) | 39.3 (34.3–44.3) | 44.7 (39.1–50.3) | 40.5 (35.7–45.3) |
| Delta efficiency, % | 27.8 (25.8–29.8) | 30.4 (28.6–32.2) | 29.2 (26.8–31.6) | 29.3 (28.1–30.5) |

Abbreviations: BW, body weight; CI, confidence interval; FFM, fat-free mass; SAT, subcutaneous adipose tissue; VAT, visceral adipose tissue; $VO_2$peak, peak aerobic capacity; %BF, percentage body fat.

[a] n = 18 due to poor quality MRI data in 2 participants.

* $P < .05$ in independent samples $t$ tests of boys versus girls.

** $P < .05$ in independent samples $t$ tests of white versus African American.

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**Table 3**

Pearson Correlations (95% CI) Between Cardiorespiratory Fitness and Body Composition and Cardiometabolic Health Markers

| | $VO_2$peak (mL/kg FFM/min) | $VO_2$peak (mL/kg BW/min) | Delta efficiency (%) |
|---|---|---|---|
| **Measure** | **n = 20** | **n = 20** | **n = 29** |
| Fat mass index | −.24 (−.57 to .15) | **−.55** * (−.80 to −.14) | .30 (−.08 to .60) |
| %BF | −.24 (−.57 to .15) | **−.60** ** (−.82 to −.21) | **.40** * (.04 to .67) |
| VAT[a] | −.10 (−.52 to .36) | −.16 (−.56 to .30) | .16 (−.22 to .50) |
| SAT[a] | **−.49** * (−.77 to −.06) | **−.68** ** (−.86 to −.34) | .11 (−.27 to .46) |
| Systolic BP (mm Hg) | −.06 (−.49 to .39) | −.03 (−.47 to .42) | −.09 (−.44 to .29) |
| Diastolic BP (mm Hg) | −.42 (−.73 to .03) | **−.52** * (−.78 to −.10) | −.03 (−.39 to .34) |
| HOMA-IR | .12 (−.34 to .53) | .02 (−.43 to .46) | −.11 (−.46 to .27) |
| LDL-C (mg/dL) | −.08 (−.51 to .38) | −.04 (−.47 to .41) | −.04 (−.40 to .33) |
| HDL-C (mg/dL) | −.08 (−.51 to .38) | −.18 (−.58 to .29) | .17 (−.21 to .51) |
| TRIG (mg/dL) | −.03 (−.47 to .42) | −.07 (−.50 to .38) | −.07 (−.43 to .30) |
| hsCRP (mg/L) | .01 (−.43 to .45) | −.23 (−.61 to .24) | **.39** * (.03 to .66) |
| Cardiometabolic risk score | −.09 (−.51 to .37) | −.16 (−.56 to .30) | −.03 (−.39 to .34) |

Abbreviations: BP, blood pressure; BW, body weight; CI, confidence interval; FFM, fat-free mass; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, homeostatic model assessment of insulin resistance; hsCRP, high-sensitivity C-reactive protein; LDL-C, low-density lipoprotein cholesterol; SAT, subcutaneous adipose tissue; TRIG, triglycerides; VAT, visceral adipose tissue; $VO_2$peak, peak aerobic capacity; %BF, percentage body fat.

Note: Bolded values reached statistical significance, at a level further defined by ** or *

** $P < .01$

* $P < .05$.

[a] n = 18/27 due to poor quality MRI data in 2 participants.

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**Table 4**

Partial Correlations (95% CI) Between $VO_2$peak (mL/kg FFM/min) (n = 20) or Delta Efficiency (n = 29) and Body Composition and Cardiometabolic Health Markers, Controlling for Age, Sex, and Race

| Measure | $VO_2$peak (mL/kg FFM/min) | Delta efficiency |
|---|---|---|
| Fat mass index | −.19 (−.64 to .36) | **.44** * (.05 to .71) |
| %BF | −.16 (−.62 to .38) | **.40** * (.01 to .69) |
| Abdominal VAT[a] | −.36 (−.74 to .19) | .22 (−.19 to .57) |
| Abdominal SAT[a] | −.44 (−.78 to .09) | .38 (−.02 to .67) |
| Systolic BP | −.18 (−.63 to .37) | −.06 (−.45 to .34) |
| Diastolic BP | −.46 (−.79 to .07) | .10 (−.31 to .48) |
| HOMA-IR | .00 (−.51 to .51) | −.16 (−.52 to .25) |
| LDL-C | −.08 (−.57 to .45) | −.21 (−.56 to .20) |
| HDL-C | .05 (−.47 to .55) | .12 (−.29 to .49) |
| TRIG | −.29 (−.70 to .26) | −.07 (−.45 to .33) |
| hsCRP | .03 (−.49 to .53) | **.48** * (.11 to .74) |
| Cardiometabolic risk score | −.37 (−.74 to .18) | .00 (−.39 to .40) |

Abbreviations: BP, blood pressure; CI, confidence interval; FFM, fat-free mass; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, homeostatic model assessment of insulin resistance; hsCRP, high-sensitivity C-reactive protein; LDL-C, low-density lipoprotein cholesterol; SAT, subcutaneous adipose tissue; TRIG, triglycerides; VAT, visceral adipose tissue; $VO_2$peak, peak aerobic capacity; %BF, percentage body fat.

Note: Bolded values reached statistical significance

* $P < .05$.

[a] n = 18/27 due to poor quality MRI data in 2 participants.