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Fatness, Fitness, and Cardiometabolic Risk Factors among Sixth-Grade Youth

RUSSELL JAGO¹, KIMBERLY L. DREWS², ROBERT G. MCMURRAY³, DEBBE THOMPSON⁴, STELLA L. VOLPE⁵, ESTHER L. MOE⁶, JOHN M. JAKICIC⁷, TRANG H. PHAM², STEVE BRUECKER⁸, TARA B. BLACKSHEAR⁹, and ZENONG YIN¹⁰

¹Department of Exercise, Nutrition & Health Sciences, University of Bristol, Bristol, England, UNITED KINGDOM

²The George Washington University Biostatistics Center, Washington, DC

³Department of Exercise & Sport Science, University of North Carolina at Chapel Hill, Chapel Hill, NC

⁴USDA/ARS Children's Nutrition Research Center, Baylor College of Medicine, Houston, TX

⁵Division of Biobehavioral and Health Sciences, University of Pennsylvania, School of Nursing, Philadelphia, PA

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Address for correspondence: Russell Jago, Ph.D., Department of Exercise, Nutrition and Health Sciences, Centre for Sport, Exercise and Health, University of Bristol, Tyndall Ave., Bristol, England, BS8 1TP, United Kingdom; russ.jago@gmail.com..

The writing group for this article was the following: R. Jago (chair), K. L. Drews, R. G. McMurray, D. Thompson, S. L. Volpe, E. L. Moe, J. M. Jakicic, T. H. Pham, S. Bruecker, T. B. Blackshear, and Z. Yin.

The HEALTHY Study Group (* indicates principal investigator or director):

STOPP-T2D study chair

Children's Hospital Los Angeles: F. R. Kaufman

Field centers

Baylor College of Medicine: T. Baranowski*, L. Adams, J. Baranowski, A. Canada, K. W. Cullen, M. H. Dobbins, R. Jago, A. Ocegueda, A. X. Rodriguez, C. Speich, L. T. Tatum, D. Thompson, M. A. White, and C. G. Williams

Oregon Health & Science University: L. Goldberg*, D. Cusimano, L. DeBar, D. Elliot, H. M. Grund, K. Kuehl, S. McCormick, E. Moe, J. B. Roullet, A. Sleight, and D. Stadler

Temple University: G. D. Foster* (Steering Committee Chair), J. Brown, B. Creighton, M. Faith, E. G. Ford, H. Glick, S. Kumanyika, J. Nachmani, J. Rosen, L. Rosen, S. Sherman, S. Solomon, A. Virus, S. L. Volpe, and S. Willi

University of California at Irvine: D. Cooper*, S. Bassin, S. Bruecker, D. Ford, P. Galassetti, S. Greenfield, J. Hartstein, M. Krause, N. Opgrand, Y. Rodriguez, and M. Schneider

University of North Carolina at Chapel Hill: J. S. Harrell*, A. Anderson, T. Blackshear, J. Buse, J. Bridgman, A. Gerstel, C. Giles, W. Hall, A. Jessup, P. Kennel, R. Matthews, R. G. McMurray, D. Rubin, A. M. Siega-Riz, M. Smith, A. Steckler, A. Stringer, and A. Zeveloff

University of Pittsburgh: M. D. Marcus*, M. Carter, S. Clayton, B. Gillis, K. Hindes, J. M. Jakicic, R. Meehan, R. Noll, T. Songer, J. Vanucci, and E. M. Venditti

University of Texas Health Science Center at San Antonio: R. Treviño*, A. Garcia, D. Hale, A. E. Hernandez, I. Hernandez, C. Mobley, T. Murray, K. Surapiboonchai, and Z. Yin

Other investigators

K. Resnicow, University of Michigan; M. Goran, University of Southern California; M. Engelgau, L. Y. Wang, and P. Zhang, Centers for Disease Control and Prevention

Coordinating center

George Washington University: K. Hirst*, K. L. Drews, S. Edelstein, L. El ghormli, L. S. Firrell, M. Huang, P. K. Feit, S. L. Mazzuto, T. Pham, and A. Wheeler

Project office

National Institute of Diabetes and Digestive and Kidney Diseases: B. Linder*, C. Hunter, M. Staten

Central blood laboratory

University of Washington Northwest Lipid Metabolism and Diabetes Research Laboratories: S. M. Marcovina*

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⁶Division of Health Promotion and Sports Medicine, Oregon Health & Sciences University, Portland, OR

⁷Department of Health and Physical Activity, University of Pittsburgh, Pittsburgh, PA

⁸Department of Health and Physical Activity, University of California at Irvine, Irvine, CA

⁹Health and Physical Education, Cairo American College, Cairo, EGYPT

¹⁰Department of Health and Kinesiology, University of Texas at San Antonio, San Antonio, TX

Abstract

Purpose—Examine whether cardiometabolic risk factors are predicted by fitness or fatness among adolescents.

Methods—Participants are 4955 (2614 female) sixth-grade students with complete data from 42 US middle schools. Fasting blood samples were analyzed for total cholesterol, HDL- and LDL-cholesterol, triglyceride, glucose, and insulin concentrations. Waist circumference and blood pressure were assessed. Body mass index (BMI) was categorized as normal weight, overweight, or obese as a measure of fatness. Fitness was assessed using the multistage shuttle test and was converted into gender-specific quintiles. Gender-specific regression models, adjusted for race, pubertal status, and household education, were run to identify whether BMI group predicted risk factors. Models were repeated with fitness group and both fitness and fatness groups as predictors.

Results—Means for each risk factor (except HDL, which was the reverse) were significantly higher ($P < 0.0001$) with increased fatness and differed across all BMI groups ($P < 0.001$). Waist circumference, LDL-cholesterol, triglycerides, diastolic blood pressure, and insulin were inversely associated with fitness ($P < 0.001$). When both fatness and fitness were included in the model, BMI was associated ($P < 0.001$) with almost all cardiometabolic risk factors; fitness was only associated with waist circumference (both genders), LDL-cholesterol (males), and insulin (both genders). Other associations between fitness and cardiometabolic risk factors were attenuated after adjustment for BMI group.

Conclusions—Both fatness and fitness are associated with cardiometabolic risk factors among sixth-grade youth, but stronger associations were observed for fatness. Although maintaining high levels of fitness and preventing obesity may positively affect cardiometabolic risk factors, greater benefit may be obtained from obesity prevention.

Keywords

FIT; OBESITY; CHILDREN; ADOLESCENTS; CARDIOVASCULAR DISEASE

Data from the 1999–2002 US National Health and Nutrition Examination Survey indicated that less than one-third of 12- to 19-yr-old adolescents in the United States met fitness recommendations (28). Low aerobic fitness levels have been associated with increased risk for cardiovascular diseases (21) and diabetes mellitus among adults (23). In children and adolescents, low aerobic fitness has also been associated with cardiometabolic (5) risk factors (large waist circumference, high blood pressure, and high insulin, glucose, and lipid levels) (15). Data from 9- and 15-yr-old youths participating in the European Youth Heart Study indicated that low aerobic fitness was associated with increased waist circumference, insulin, glucose, and lipid concentrations and a clustered score that included all of the cardiometabolic risk factors (13). Interestingly, the researchers also found that these associations were independent of both physical activity (the behavior that influences fitness) and fatness (13).

Extensive research has shown that the risk of cardiovascular disease and diabetes among overweight adults is ameliorated if the adult has a high level of fitness (22,32). For example, data from the Cooper Clinic in Dallas showed that unfit, lean men had double the risk of cardiovascular disease and all-cause mortality than lean men who were fit (22). Moreover, unfit lean men had a higher risk of cardiovascular disease and all-cause mortality than fit but overweight men (22). These findings suggest that fitness offers a degree of protection against cardiovascular disease and mortality even if the individual is overweight. Similar findings have been reported for women (32). Although there is a lack of evidence about the associations among childhood fitness, adiposity, and mortality, the prevalence of cardiometabolic risk factors has been shown to increase with higher levels of obesity among youth (20,31). Higher levels of obesity among children and adolescents have also been associated with low levels of aerobic fitness (16). Comparable associations among fitness, adiposity, and cardiometabolic risk factors findings have also been reported among a relatively small (296 boys and 188 girls) sample of 8- to 18-yr-old US youths (12). It is not clear if associations are evident for all cardiometabolic risk factors among adolescents. Understanding the importance of fitness, obesity status, and the prevalence of cardiometabolic risk factors among adolescents will provide key information to aid the design of strategies to reduce the prevalence of cardiometabolic risk factors among adolescents, thereby reducing disease risk.

Boys have higher levels of aerobic fitness than girls (28), with some evidence of ethnic differences in fitness levels (16). Maturation differences in both fitness (28) and cardiometabolic risk factors have also been reported (39). Thus, in examining the associations among fitness, obesity, and cardiometabolic risk factors, it is important to account for these biological and sociodemographic factors. It is also important to recognize that the majority of previous studies that have examined associations between aerobic fitness and cardiometabolic risk factors among youth have reported fitness in relation to body mass ($\text{mL O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ or $\text{W} \cdot \text{kg}^{-1}$) (4,30), which precludes the necessary examination of the independent effects of fitness and fatness. In light of the evidence presented above, the aim of this article was to examine the extent to which fitness and obesity status are independently associated with cardiometabolic risk factors among a large, ethnically diverse sample of sixth-grade US adolescents.

METHODS

Sample

Data were collected as part of the baseline assessment of the HEALTHY Study, a National Institute of Diabetes and Digestive and Kidney Diseases multisite study designed to reduce the prevalence of risk factors for type 2 diabetes mellitus among middle school children (7,18). Data were collected at seven field centers (Baylor College of Medicine, Houston, TX; Oregon Health & Science University, Portland, OR; University of California at Irvine, Irvine, CA; Temple University, Philadelphia, PA; University of North Carolina at Chapel Hill, Chapel Hill, NC; University of Pittsburgh, Pittsburgh, PA; and University of Texas Health Science Center at San Antonio, San Antonio, TX), with a coordinating center in Washington, DC (George Washington University Biostatistics Center). Participants were recruited from 42 middle schools, 6 per field center. Schools were required to have at least 50% of students eligible for free or reduced-price lunch or belonging to a minority group and an annual student attrition rate from all causes $\leq 25\%$. All sixth-grade students were invited to participate in a "health screening." Students were given a \$50 incentive for data collection. This study was approved by the institutional review boards at each field center, and written informed parental consent and child assent were obtained.

Procedures

Measurements were conducted by personnel who were trained and certified in recording height, weight, and waist circumference accurately. Height and body mass were measured without shoes using the Prospective Enterprises PE-AIM-101 stadiometer and the SECA Corporation Alpha 882 electronic scale. Body mass index (BMI; $\text{kg}\cdot\text{m}^{-2}$), which provides an index of overweight or obesity, was calculated and, for the purposes of this article, was interpreted as an indicator of “fatness.” Waist circumference was taken using a Gulick tape measure (G-tape) with a tension device on bare skin measured just above the iliac crest. Blood pressure was recorded three times using an automated blood pressure monitor (HEM-907XL; Omron, Vernon Hills, IL). The initial value was recorded after the participant had been seated quietly for 5 min with each subsequent value recorded 1 min after the preceding recording. An appropriate size cuff was used for all participants. The mean of the second and third recordings was used in all subsequent analyses.

Pubertal status was self-reported individually in private using the Pubertal Development Scale (29) and was converted to pubertal stage groups that are consistent with the five pubertal stages that have been outlined by Tanner (33). Ethnicity and race were collected by student self-report in response to two separate items. Frequently, this age group did not understand the distinction between ethnicity and race, and the information from both items was combined and categorized as follows: anyone checking “Hispanic or Latino” ethnicity was classified as Hispanic, non-Hispanics choosing only “black or African American” race were classified as black, non-Hispanics choosing only “white” race were white, and all other response categories were combined into “other.” A parent or guardian completed a questionnaire providing the highest level of education in the household. On the basis of these responses, the highest household education level was classified as low (less than high school or some high school), middle (high school graduate or some college or specialized training), or high (college or university graduate or postgraduate training or degree).

Fitness was assessed using the 20-m shuttle test (20-MST) (24,25), most frequently during a physical education class. The test required students to run back and forth between two lines set 20 m apart. The running pace was determined by audio signals emitted from a pre-recorded CD. The test started at $8.5 \text{ km}\cdot\text{h}^{-1}$ and increased by $0.5 \text{ km}\cdot\text{h}^{-1}$ with each subsequent level. The test was completed when the participant was not able to complete the distance at the stipulated pace on two laps. A score for the test was based on the number of laps completed, and for the reasons outlined above, this score was not adjusted for body mass.

Participants were called the night before data collection to remind them not to eat or drink anything but water after midnight and were asked at the beginning of the blood screening when they last ate. Participants who reported eating after midnight were considered nonfasting and asked to return another day. Experienced pediatric phlebotomists obtained fasting blood samples that were processed and then shipped to the central blood laboratory at the University of Washington Northwest Lipid Research Laboratories for all analyses. Analyses of glucose were performed on a Roche P module autoanalyzer by the hexokinase method using reagent from Roche Diagnostics (Indianapolis, IN). Insulin was measured by a two-site immunoenzymometric assay performed using a Tosoh 1800 autoanalyzer (Tosoh Biosciences Inc., San Francisco, CA). The assay sensitivity level was $2.0 \mu\text{U}\cdot\text{mL}^{-1}$, with interassay and intra-assay coefficients of variation $<10\%$. The assay had a high specificity as cross-reactivity with human C-peptide and pro-insulin was 0% and 2%, respectively. Measurements of total plasma cholesterol, cholesterol in the lipoprotein fractions, and triglycerides were performed enzymatically on the Roche Modular-P autoanalyzer using methods standardized to the Centers for Disease Control and Prevention reference methods (37). Determination of HDL-cholesterol was performed after precipitation of apolipoprotein

B-containing particles by dextran sulfate Mg^{2+} . LDL-cholesterol was calculated using the equation of Friedewald et al. (14). This approach for calculating LDL is clinically reliable if the measurements of total and HDL-cholesterol are performed with a high level of accuracy and triglycerides are $<400 \text{ mg-dL}^{-1}$ (38). In the case of elevated triglycerides, a complete lipoprotein separation by ultracentrifugation, which allows quantization of the individual lipoprotein classes, was performed using the Lipid Research Clinics Beta Quantification procedure (17). The interassay coefficients of variations are consistently $<1.5\%$ for total cholesterol and triglycerides and $<2\%$ for HDL-cholesterol.

Statistical analysis

A total of 6358 sixth-grade students participated in the HEALTHY Study at baseline. Of these participants, 5394 had complete data for anthropometric assessments, blood values, 20-MST, pubertal stage survey, and parental or guardian report of highest level of household education. However, 439 of these participants reported other or mixed race and were dropped from all analysis because the results for this ethnic group are too heterogeneous to interpret. Therefore, analyses are presented for the remaining 4955 participants (2614 females). Pubertal data were collapsed into three groups, prepubertal (stage 1), early pubertal (stages 2 and 3), and pubertal (stages 4 and 5).

Descriptive statistics with means and SE for continuous measures and frequency distribution for categorical variables are presented in Table 1, both overall and by gender for the complete sample listed above. Fitness category was determined by quintiles on the basis of the number of laps for both genders, which are inexact because of ties. BMI percentile by age and gender was calculated using the Centers for Disease Control and Prevention 2000 criteria (8,9). Youth with BMI ≥ 85 th but <95 th percentile were classified as overweight, and those with BMI ≥ 95 th percentile were classified as obese (1). In this study, the three-level BMI-based obesity status is used as a proxy of fatness.

Separate regression models were fitted for each continuous cardiometabolic risk factor using the PROC GLIMMIX procedure with either fitness or BMI group as an exposure measure. To adjust for the clustering of participants within schools, a random effect for school was included in the models. Because one-way ANOVA tests indicated that there were gender differences for both fitness ($P < 0.0001$) and BMI categories ($P < 0.0013$), models were run separately for males and females. All models were adjusted for pubertal stage group, race, and household education. Adjusted least-square means and 95% confidence intervals were obtained from the model, with the overall P values for a test of group differences (Tables 2 and 3). Where there were statistically significant group differences ($P < 0.01$), pairwise comparisons were carried out to determine which differences between categories were statistically significant. To account for multiple testing, Bonferroni P value adjustments were performed for all pairwise comparisons.

Models including both BMI and fitness categories were fitted to examine whether their concurrent relationships with each cardiometabolic risk factor changed from the initial sets of models where BMI and fitness categories were entered into the model separately (Table 4). The models were adjusted for pubertal stage group, race, and household education. To aid in the interpretation of each model, overall F test statistic values are presented (Table 4). As another measure of model fit, the Akaike Information Criterion (AIC) is also presented (Table 4). The AIC is $AIC = 2k - 2\ln(L)$, where k is the number of parameters in the statistical model and L is the maximized value of the likelihood function for the estimated model. The AIC is not a test on the model in the sense of hypothesis testing; rather, it is a tool for model selection. Given a data set, competing models may be ranked according to their AIC. In terms of interpretation, the model with the lowest AIC provides the best model fit (6).

Further analyses were also conducted using BMI percentile and number of laps as continuous variables instead of the categorical approach reported above; however, as similar results were observed for these models, findings are not reported here. The data presented here are from the baseline data collection of a cluster-randomized controlled trial in which the effect of a multicomponent intervention is being tested to prevent risk factors for type 2 diabetes. Therefore, although to take account of the multiple tests performed α was set at 0.01, all P values reported within this article represent exploratory findings because the study was powered to test the effect of the intervention on the final primary outcomes only. All analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC).

RESULTS

As shown in Table 1, the sample that was included in the analysis was 58.6% Hispanic, 20.8% black, and 20.7% white and included a spread of pubertal stages and socioeconomic groups (Table 1). A little more than half (50.6%) of the participants were normal weight (BMI <85th percentile) with 30.0% obese (BMI $\geq$ 95th percentile). One-way ANOVA tests indicated that there were gender differences for both fitness ($P < 0.0001$) and BMI categories ($P < 0.0013$), with higher levels of obesity among the males and lower levels of fitness among the girls. The distribution of fitness laps and the associated quintile thresholds are presented separately for males and females in Figure 1. There was an approximately even distribution of girls (631, 554, 385, 573, and 471) and boys (560, 438, 433, 458, and 452) within each quintile, with the slight variations in quintile size because of ties in the number of laps. The gender-specific fitness quintiles were as follows: level 1 = 0–11 laps for both males and females, level 2 = 12–16 laps for males and 12–15 laps for females, level 3 = 17–24 laps for males and 16–18 laps for females, level 4 = 25–35 laps for males and 19–26 laps for females, and level 5 = 36–89 laps for males and 27–74 laps for females.

Means and 95% confidence intervals for each of the cardiometabolic risk factors are presented for BMI groups for both genders in Table 2. The mean values for each risk factor (except HDL which was the reverse) increased across the obesity groups ($P < 0.001$), with values highest for the obese group (BMI $\geq$ 95th percentile) and lowest for the normal weight group (BMI <85th percentile). Follow-up tests indicated that waist circumference, HDL-cholesterol, triglycerides, diastolic blood pressure, and insulin were different among each of the three BMI groups for both genders.

Means and 95% confidence intervals for each of the cardiometabolic risk factors are presented stratified by gender-specific fitness quintiles for both genders in Table 3. Waist circumference, LDL-cholesterol, triglycerides, diastolic blood pressure, and insulin were all inversely associated with fitness quintiles, with higher levels of fitness associated with lower risk factor means in both boys and girls. HDL-cholesterol levels were positively associated with fitness quintiles in both boys and girls, with higher levels of HDL associated with higher quintiles of fitness. Fitness quintiles were not associated with girls' total cholesterol or the systolic blood pressure and with glucose levels of either gender. Follow-up tests indicated that, with the exception of male waist circumference, there were no significant differences between the cardiometabolic risk factor levels of all quintiles. For example, for girls' LDL-cholesterol, there was only a significant difference between the lowest and top two highest quintiles of fitness. Moreover, only waist circumference and insulin were significantly different between the first and second quintiles of fitness. Similarly, very few of the comparisons between adjacent fitness quintiles (e.g., 2 vs 3) were significant for most of the cardiometabolic risk factors. Collectively, these findings demonstrate a pattern whereby, although cardio-metabolic risk factors differed by quintiles of fitness, differences tended to be statistically significant only when nonadjacent groups with greater differences in fitness levels were compared.

Table 4 presents a comparison of models when BMI group, fitness group, or both BMI group and fitness group were included in models to predict cardiometabolic risk factors. When both BMI group and fitness were included in the model together, BMI group was a significant predictor of all cardiometabolic risk factors except girls' total cholesterol. In the same models, fitness was associated only with waist circumference (both genders), LDL-cholesterol (males), systolic blood pressure (males), and insulin (both genders). Models that included BMI alone or both fitness and BMI had lower AIC values than models that just included fitness. In four models, AIC did not improve with the addition of fitness to models that included BMI; these models were HDL in males, triglycerides in males, triglycerides in females, and glucose in females. Because lower AIC values indicate improved model fit, the analyses demonstrate that, in all instances, including both BMI group and fitness quintiles in the analysis improved the prediction of cardiometabolic risk factors.

DISCUSSION

The data presented in this article revealed that both fitness and fatness were associated with cardiometabolic risk factors among a large, ethnically diverse sample of US sixth-grade students. *Post hoc* tests indicated with a few exceptions that there were significant differences in cardiometabolic risk factor levels between each of the three BMI groups, but fitness-based differences tended to be significant only when non-adjacent fitness groups were compared. It is also important to highlight that several associations between fitness and cardiometabolic risk factors were attenuated after adjustment for fatness, indicating that fatness is likely to be the more dominant predictor of cardiometabolic risk factors at this age.

These findings are consistent with several previous childhood studies (10,11) including a recent article that reported that fatness was a stronger predictor of cardiometabolic risk factors than fitness among a cohort white and African American youth from North Carolina (27). The data presented here extend those findings by demonstrating in a unique, ethnically diverse cohort of adolescents recruited from across the United States that fatness is a stronger predictor of cardiometabolic risk factors than fitness among youth. The data also show that although cardiometabolic risk levels increased with each BMI group, the fitness differences tended to only be evident when nonsequential fitness quintiles were compared. Similar findings have also been observed in data from the Aerobics Center Longitudinal Study, where the differences in metabolic risk score were accounted for by BMI levels but not by fitness in males aged 8–18 yr (12). Collectively, these findings indicate that, whereas preventing weight gain and improving fitness are both likely to be helpful in maintaining lower levels of cardiometabolic risk factors among youth, greater emphasis on obesity prevention is warranted.

Comparison of the data presented in this study and published adult studies suggests that the importance of fitness changes with age and the development of lifestyle diseases such as type 2 diabetes. The Look Ahead study of overweight or obese adults with type 2 diabetes reported that, among females, fitness was a significant predictor of triglycerides but BMI was not and that only fitness predicted the Framingham risk factor scores for both genders (41). Comparison of the studies might suggest that, among a disease-free sample of young adolescents, fatness is more closely associated with cardiometabolic risk factors than aerobic fitness, but associations may change with the development of obesity and type 2 diabetes mellitus. Fat cell size increases during obesity and is likely to have a direct effect on pathophysiology and, therefore, also risk factor profile. Because fitness is heavily influenced by genetic factors (3), it may take a while for the well-established associations between adult fitness and cardiometabolic risk factors and mortality risk to develop, only becoming evident in adulthood (22,32). It is, however, important to acknowledge that, in the present study, only 0.2% males and 2.5% females would be categorized as above average fitness using the

FITNESSGRAM cutoff criteria (40). Therefore, to assess associations with a range of fitness levels, we created gender-specific fitness quintiles instead of using the dichotomous FITNESSGRAM criteria in our analysis. This approach limits our ability to draw conclusions about “fit” versus “unfit” adolescents. In addition, the low levels of fitness and the lack of highly fit adolescents could have attenuated the relationship between fitness and the cardiometabolic risk factors.

Consistent with previous studies, the girls in this study had lower levels of fitness than boys (19,34). Therefore, although the associations between fitness and cardiometabolic risk reported here suggest a need to develop interventions aimed at maintaining adolescent fitness, there is a particular need to develop strategies to increase girls' fitness. This is particularly important because low levels of fitness track into adulthood (35), thus increasing the importance that children, especially girls, develop habits to promote and maintain fitness that will benefit them later in life.

Strengths and limitations

This study has extended the current literature base by providing new information about the associations among fitness, obesity, and cardiometabolic risk factors among a large, ethnically diverse sample of sixth-grade youth. This study does, however, have some limitations that need to be recognized. Although the 20-MST has been strongly associated ($r = 0.69-0.96$) (2,26,36) with aerobic fitness in laboratory tests, the 20-MST does not directly measure aerobic fitness. Validity of estimated aerobic fitness is largely influenced by levels of maximal exertion or motivation of participants. Therefore, 20-MST only provides an estimate of fitness. The study is also limited by the single age group, which precludes an assessment of age or maturation-related differences in associations. It is also important to recognize that although a validated scale was used, pubertal stage was self-reported by the participants and could therefore be prone to a degree of measurement error. Finally, because the study is cross-sectional, it is not possible to identify directions of associations or causation between variables of interest.

In conclusion, the data presented in this article have shown that, among a large, ethnically diverse cohort of US youth, both fatness and fitness are associated with cardiometabolic risk factors. Associations were, however, stronger for fatness than fitness, and several fitness associations were attenuated after controlling for fatness. Results, therefore, suggest that although maintaining high levels of fitness and preventing obesity may positively affect cardiometabolic risk factors, the greater benefit may be obtained from obesity prevention, and there is a need to redouble efforts in this area.

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FIGURE 1.

Fitness and quintile break points for males and female adolescents in the HEALTHY Study.

TABLE 1

Baseline characteristics overall and by gender for the $n = 4955$ participants completing anthropometric measures, blood collection, and 20-MST for whom highest household education level was also available.

Demographic Characteristics	Overall		Males		Females	
	<i>n</i>	Mean $\pm$ SE or %	<i>n</i>	Mean $\pm$ SE or %	<i>n</i>	Mean $\pm$ SE or %
Age (yr)	4955	11.3 $\pm$ 0.6	2341	11.4 $\pm$ 0.6	2614	11.3 $\pm$ 0.6
Pubertal status						
Stage 1	521	10.5	369	15.8	152	5.8
Stage 2 or 3	3251	65.6	1821	77.8	1430	54.7
Stage 4 or 5	1183	23.9	151	6.5	1032	39.5
Race/ethnicity						
White (non-Hispanic)	1024	20.7	527	22.5	497	19.0
Black	1029	20.8	457	19.5	572	21.9
Hispanic	2902	58.6	1357	58.0	1545	59.1
Highest household education level						
Low	1432	28.9	665	28.4	767	29.3
Middle	2628	53.0	1237	52.8	1391	53.2
High	895	18.1	439	18.8	456	17.4
Fitness and obesity measures						
BMI ($\text{kg}\cdot\text{m}^{-2}$)	4955	22.3 $\pm$ 5.4	2341	22.4 $\pm$ 5.4	2614	22.3 $\pm$ 5.3
BMI category						
<85th percentile	2505	50.6	1127	48.1	1378	52.7
85th–94th percentile	964	19.5	432	18.5	532	20.4
$\geq$ 95th percentile	1486	30.0	782	33.4	704	26.9
Fitness (no. of laps)	4955	21.1 $\pm$ 12.1	2341	23.8 $\pm$ 14.0	2614	18.7 $\pm$ 9.5
Cardiometabolic risk factors						
Waist circumference (cm)	4955	75.9 $\pm$ 14.9	2341	76.0 $\pm$ 15.9	2614	75.7 $\pm$ 13.9
Total cholesterol ($\text{mg}\cdot\text{dL}^{-1}$)	4955	156.9 $\pm$ 27.1	2341	158.5 $\pm$ 27.9	2614	155.5 $\pm$ 26.4
HDL-cholesterol ($\text{mg}\cdot\text{dL}^{-1}$)	4955	52.5 $\pm$ 12.2	2341	52.9 $\pm$ 12.5	2614	52.1 $\pm$ 12.0
LDL-cholesterol ($\text{mg}\cdot\text{dL}^{-1}$)	4955	86.7 $\pm$ 23.1	2341	88.1 $\pm$ 23.4	2614	85.4 $\pm$ 22.7
Triglycerides ($\text{mg}\cdot\text{dL}^{-1}$)	4955	88.8 $\pm$ 51.0	2341	87.7 $\pm$ 52.0	2614	89.9 $\pm$ 50.0

Demographic Characteristics	Overall		Males		Females	
	<i>n</i>	Mean ± SE or %	<i>n</i>	Mean ± SE or %	<i>n</i>	Mean ± SE or %
SBP (mm Hg)	4955	107.6 ± 10.1	2341	108.4 ± 10.2	2614	106.9 ± 9.9
DBP (mm Hg)	4955	63.7 ± 8.7	2341	63.5 ± 8.8	2614	63.8 ± 8.6
Glucose (mg·dL ⁻¹)	4955	93.5 ± 6.6	2341	94.5 ± 6.6	2614	92.6 ± 6.6
Insulin (μU·mL ⁻¹)	4955	13.2 ± 11.1	2341	12.0 ± 11.6	2614	14.2 ± 10.6

DBP, diastolic blood pressure; SBP, systolic blood pressure.

TABLE 2

Means and 95% confidence intervals for cardiometabolic risk factor by BMI category adjusted for race, household education level, and pubertal stage (males $n = 2341$, females $n = 2614$).

Cardiometabolic Risk Factor	Gender	BMI Category			Pr > F
		<85th percentile ^a	85th–94th percentile ^a	≥95th percentile ^a	
Waist circumference (cm)	Male	63.8 (63.0–64.6)	75.9 (74.9–77.0)	93.2 (92.3–94.1)	<0.0001 ^{c,d,e}
	Female	65.3 (64.5–66.1)	77.6 (76.7–78.5)	92.9 (92.0–93.8)	<0.0001 ^{c,d,e}
Total cholesterol (mg·dL ⁻¹)	Male	154.1 (151.7–157.1)	159.2 (155.8–162.6)	164.4 (161.4–167.3)	<0.0001 ^d
	Female	156.1 (154.0–158.2)	160.1 (157.3–162.8)	160.5 (158.0–163.1)	0.0002 ^d
HDL-cholesterol (mg·dL ⁻¹)	Male	57.9 (56.8–59.1)	51.6 (50.1–53.1)	46.4 (45.2–47.7)	<0.0001 ^{c,d,e}
	Female	56.9 (55.8–58.0)	50.7 (49.4–52.0)	46.0 (44.7–47.2)	<0.0001 ^{c,d,e}
LDL-cholesterol (mg·dL ⁻¹)	Male	83.5 (81.4–85.6)	90.4 (87.7–93.2)	95.7 (93.4–98.1)	<0.0001 ^{c,d,e}
	Female	85.0 (83.2–86.8)	90.7 (88.4–93.1)	92.8 (90.6–95.0)	<0.0001 ^{c,d}
Triglycerides (mg·dL ⁻¹) ^b	Male	60.1 (57.7–62.5)	75.7 (71.8–79.9)	98.3 (94.0–102.8)	<0.0001 ^{c,d,e}
	Female	66.1 (64.0–68.4)	83.3 (79.7–87.0)	95.9 (92.1–99.9)	<0.0001 ^{c,d,e}
SBP (mm Hg)	Male	106.8 (105.7–107.9)	107.4 (106.0–108.7)	112.5 (111.3–113.7)	<0.0001 ^{d,e}
	Female	105.1 (104.1–106.1)	106.2 (105.0–107.4)	109.4 (108.3–110.5)	<0.0001 ^{d,e}
DBP (mm Hg)	Male	61.2 (60.4–61.9)	63.1 (62.1–64.1)	67.7 (66.9–68.6)	<0.0001 ^{c,d,e}
	Female	62.3 (61.6–63.0)	64.3 (63.4–65.2)	68.1 (67.2–68.9)	<0.0001 ^{c,d,e}
Glucose (mg·dL ⁻¹)	Male	93.5 (92.9–94.2)	94.3 (93.5–95.1)	94.7 (94.0–95.4)	0.0003 ^d
	Female	91.6 (91.0–92.2)	92.0 (91.3–92.7)	93.2 (92.5–93.9)	<0.0001 ^d
Insulin (μU·mL ⁻¹) ^b	Male	6.1 (5.8–6.4)	9.6 (9.0–10.2)	16.0 (15.2–16.9)	<0.0001 ^{c,d,e}
	Female	7.7 (7.3–8.0)	12.0 (11.3–12.7)	18.2 (17.3–19.2)	<0.0001 ^{c,d,e}

^aNumber of participants in each category: <85th percentile, males $n = 1127$ and females $n = 1378$; 85th–94th percentile, males $n = 432$ and females $n = 732$ and females $n = 704$.

^bVariables were log-transformed for analysis, means and 95% confidence intervals were transformed back to the original scale.

^cBonferroni $P \leq 0.001$, <85th percentile vs 85th–94th percentile.

^d Bonferroni $P \leq 0.001$, <85th percentile vs ≥ 95 th percentile.

^e Bonferroni $P \leq 0.001$, 85th–94th percentile vs ≥ 95 th percentile.

TABLE 3

Means and confidence intervals for cardiometabolic disease risk factor by fitness level adjusted for race, household education level, and pubertal stage (males $n = 2341$, females $n = 2614$).

Cardiometabolic Risk Factor	Gender	Fitness Category ^a					Pr > F
		Level 1	Level 2	Level 3	Level 4	Level 5	
Waist circumference (cm)	Male	87.5 (85.9–89.1)	79.3 (77.5–81.0)	73.0 (71.3–74.8)	68.6 (66.9–70.3)	64.3 (62.6–66.0)	<0.0001 ^{b–k}
	Female	85.1 (83.6–86.6)	76.6 (75.0–78.2)	72.1 (70.5–73.8)	69.3 (67.7–70.8)	65.3 (63.7–66.9)	<0.0001 ^{b–h,j,k}
Total cholesterol (mg·dL ⁻¹)	Male	163.4 (160.2–166.6)	159.3 (155.9–162.7)	159.5 (156.0–162.9)	155.2 (151.9–158.6)	153.5 (150.1–156.8)	<0.0001 ^{d,e}
	Female	160.1 (157.5–162.7)	159.1 (156.3–161.9)	159.3 (156.3–162.4)	156.0 (153.2–158.8)	155.1 (152.3–158.0)	0.0071
HDL-cholesterol (mg·dL ⁻¹)	Male	48.9 (47.5–50.4)	50.9 (49.4–52.4)	54.1 (52.5–55.6)	55.7 (54.2–57.2)	57.7 (56.2–59.2)	<0.0001 ^{c–h,j}
	Female	49.4 (48.1–50.7)	51.6 (50.3–53.0)	53.5 (52.0–55.0)	54.8 (53.4–56.1)	56.9 (55.5–58.3)	<0.0001 ^{c–e,g,h,j}
LDL-cholesterol (mg·dL ⁻¹)	Male	94.6 (92.0–97.1)	89.9 (87.1–92.6)	89.2 (86.4–92.0)	85.2 (82.5–88.0)	82.5 (79.8–85.2)	<0.0001 ^{d–e,h,j}
	Female	91.3 (89.1–93.6)	88.9 (86.5–91.3)	89.4 (86.7–92.0)	86.0 (83.7–88.4)	84.0 (81.6–86.4)	<0.0001 ^{d,e}
Triglycerides (mg·dL ⁻¹) ^f	Male	86.5 (81.9–91.4)	80.8 (76.2–85.7)	71.6 (67.5–76.0)	65.3 (61.6–69.2)	60.8 (57.4–64.5)	<0.0001 ^{c–e,g,h,j}
	Female	86.0 (82.4–89.9)	81.5 (77.8–85.4)	74.1 (70.4–78.0)	69.5 (66.4–72.8)	66.9 (63.7–70.1)	<0.0001 ^{c–e,g,h}
SBP (mm Hg)	Male	109.4 (108.2–110.7)	109.1 (107.7–110.4)	108.6 (107.2–109.9)	108.0 (106.7–109.3)	108.2 (106.9–109.6)	0.1753
	Female	106.9 (105.8–108.0)	106.7 (105.5–107.9)	106.4 (105.1–107.6)	105.8 (104.6–106.9)	106.0 (104.8–107.2)	0.2861
DBP (mm Hg)	Male	66.0 (65.0–67.0)	64.6 (63.6–65.7)	63.3 (62.2–64.3)	62.4 (61.4–63.5)	60.9 (58.9–62.0)	<0.0001 ^{c–e,h,j}
	Female	66.3 (65.4–67.2)	64.9 (64.0–65.8)	64.0 (63.0–65.0)	62.8 (61.8–63.7)	61.9 (61.0–62.9)	<0.0001 ^{c–e,g,h}
Glucose (mg·dL ⁻¹)	Male	94.6 (93.9–95.3)	94.1 (93.3–95.0)	93.6 (92.8–94.4)	93.8 (93.0–94.6)	93.7 (93.0–94.5)	0.1177
	Female	92.5 (91.8–93.2)	92.1 (91.4–92.8)	92.4 (91.6–93.2)	91.9 (91.2–92.6)	91.4 (90.7–92.2)	0.0660
Insulin (μU·mL ⁻¹) ^f	Male	13.0 (12.1–13.9)	10.6 (9.9–11.4)	8.3 (7.7–9.0)	7.1 (6.6–7.7)	6.3 (5.9–6.8)	<0.0001 ^{b–h,j}
	Female	14.3 (13.4–15.2)	11.1 (10.4–11.8)	9.9 (9.3–10.7)	9.0 (8.4–9.6)	7.6 (7.2–8.2)	<0.0001 ^{b–e,g,h,j,k}

ⁱ Bonferroni $P \leq 0.001$, level 3 vs level 4.

^a Fitness category is defined to approximate quintiles of the overall data. Exact quintiles are not achievable because of breaks occurring at partial lap numbers and ties in the number of laps. The levels or approximate quintiles were determined overall and by gender. The levels (and the number of observations) are defined as follows: males: level 1 = 0–11 laps ($n = 560$), level 2 = 12–16 laps ($n = 438$), level 3 = 17–24 laps ($n = 433$), level 4 = 25–35 laps ($n = 458$), and level 5 = 36–89 laps ($n = 452$); females: level 1 = 0–11 laps ($n = 631$), level 2 = 12–15 laps ($n = 554$), level 3 = 16–18 laps ($n = 385$), level 4 = 19–26 laps ($n = 573$), and level 5 = 27–74 laps ($n = 471$).

^b Bonferroni $P \leq 0.001$, level 1 vs level 2.

- ^c Bonferroni $P \leq 0.001$, level 1 vs level 3.
- ^d Bonferroni $P \leq 0.001$, level 1 vs level 4.
- ^e Bonferroni $P \leq 0.001$, level 1 vs level 5.
- ^f Bonferroni $P \leq 0.001$, level 2 vs level 3.
- ^g Bonferroni $P \leq 0.001$, level 2 vs level 4.
- ^h Bonferroni $P \leq 0.001$, level 2 vs level 5.
- ^j Bonferroni $P \leq 0.001$, level 3 vs level 5.
- ^k Bonferroni $P \leq 0.001$, level 4 vs level 5.
- ^l Variables were log-transformed for analysis; means and 95% confidence intervals were transformed back to the original scale.

P values of BMI and fitness categories in relation to cardiometabolic disease risk factors adjusting for race, household education level, and pubertal stage (males *n* = 2341, females *n* = 2614).

TABLE 4

Cardiometabolic Risk Factor	Gender	BMI-Only Model			Fitness-Only Model			BMI + Fitness Together Model					
		<i>P</i>	<i>F</i>	AIC	<i>P</i>	<i>F</i>	AIC	BMI			Fitness		
								<i>P</i>	<i>F</i>	AIC	<i>P</i>	<i>F</i>	AIC
Waist circumference (cm)	Male	<0.0001	2617.27	16,740.6	<0.0001	221.90	18,738.2	<0.0001	1740.29	<0.0001	<0.0001	33.50	16,607.9
	Female	<0.0001	3594.83	17,592.3	<0.0001	214.59	20,297.2	<0.0001	2579.28	<0.0001	<0.0001	36.33	17,450.9
Total cholesterol (mg·dL ⁻¹)	Male	<0.0001	30.21	22,097.0	<0.0001	9.42	22,113.1	<0.0001	15.13	0.0926	2.00	22,077.7	
	Female	0.0002	8.47	24,422.2	0.0071	3.53	24,419.3	0.0144	4.25	0.2207	1.43	24,406.0	
HDL-cholesterol (mg·dL ⁻¹)	Male	<0.0001	253.71	17,851.7	<0.0001	42.36	18,143.7	<0.0001	160.83	0.1170	1.85	17,840.3	
	Female	<0.0001	247.81	19,830.2	<0.0001	31.97	20,155.9	<0.0001	176.65	0.3796	1.05	19,822.7	
LDL-cholesterol (mg·dL ⁻¹)	Male	<0.0001	67.20	21,218.3	<0.0001	19.14	21,268.1	<0.0001	34.88	0.0077	3.48	21,194.7	
	Female	<0.0001	32.65	23,580.1	<0.0001	8.47	23,605.8	<0.0001	19.37	0.0985	1.96	23,563.2	
Triglycerides (mg·dL ⁻¹) ^a	Male	<0.0001	286.42	2830.9	<0.0001	43.70	3185.2	<0.0001	188.38	0.3552	1.10	2848.3	
	Female	<0.0001	193.20	2894.5	<0.0001	30.44	3146.5	<0.0001	132.80	0.0136	3.15	2904.5	
SBP (mm Hg)	Male	<0.0001	84.23	17,269.5	0.1753	1.59	17,423.8	<0.0001	94.01	<0.0001	6.17	17,242.0	
	Female	<0.0001	47.61	19,112.7	0.2861	1.25	19,199.5	<0.0001	49.36	0.0765	2.11	19,102.0	
DBP (mm Hg)	Male	<0.0001	145.97	16,513.2	<0.0001	24.39	16,691.9	<0.0001	95.16	0.5118	0.82	16,508.3	
	Female	<0.0001	111.24	18,412.7	<0.0001	21.85	18,539.2	<0.0001	70.50	0.0382	2.54	18,401.3	
Glucose (mg·dL ⁻¹)	Male	0.0003	8.22	15,355.0	0.1177	1.84	15,363.8	0.0034	5.70	0.6638	0.60	15,352.9	
	Female	<0.0001	14.57	17,140.4	0.0660	2.21	17,160.6	<0.0001	11.10	0.7367	0.50	17,139.2	
Insulin (μU·mL ⁻¹) ^a	Male	<0.0001	763.39	3668.6	<0.0001	104.69	4467.5	<0.0001	489.21	<0.0001	7.35	3659.6	
	Female	<0.0001	700.80	3842.8	<0.0001	83.87	4656.6	<0.0001	486.34	<0.0001	6.50	3838.4	

^aVariables were log-transformed for analysis.