Cardiorespiratory Fitness Levels Among US Youth 12 to 19 Years of Age

Findings From the 1999-2002 National Health and Nutrition Examination Survey

Russell R. Pate, PhD; Chia-Yih Wang, PhD; Marsha Dowda, DrPH; Stephen W. Farrell, PhD; Jennifer R. O’Neill, MPH

Objectives: To assess cardiorespiratory fitness levels in youth aged 12 to 19 years and to examine associations between fitness and age, sex, race/ethnicity, and self-reported physical activity in this age group.

Design: Cross-sectional study.


Participants: A representative sample of 4732 youth aged 12 to 19 years was examined; 3287 completed the treadmill test and were included in the analysis. The National Center for Health Statistics conducted the survey.

Main Exposures: Age, sex, race/ethnicity, weight status, self-reported physical activity, and television viewing.

Main Outcome Measure: Estimated maximal oxygen uptake (VO\(_{2}\)\(_{\text{max}}\)) determined by a submaximal treadmill exercise test.

Results: Estimated VO\(_{2}\)\(_{\text{max}}\) (mL·kg\(^{-1}\)·min\(^{-1}\)) was higher in males (mean±SE, 46.4±0.4) than in females (mean±SE, 38.7±0.3) but did not differ across race/ethnicity groups. Among males, older participants had higher VO\(_{2}\)\(_{\text{max}}\) values, while in females, younger participants had higher values. For both males and females, those in the normal weight group had higher fitness levels than those in the at risk for overweight and overweight groups. Approximately one third of both males and females failed to meet recommended standards for cardiorespiratory fitness.

Conclusions: In US youth, cardiorespiratory fitness is lower in males and females who are overweight than in those of normal weight, but fitness is not related to race/ethnicity. Youth who have low levels of physical activity and high levels of sedentary behavior are also more likely to have lower cardiorespiratory fitness.

Arch Pediatr Adolesc Med. 2006;160:1005-1012
tive than previous generations, it is possible that physical fitness has also declined in this population. A key component of overall physical fitness is cardiorespiratory endurance.\textsuperscript{19} Between 1999 and 2002, the National Health and Nutrition Examination Surveys (NHANES) included a measure of cardiorespiratory fitness, which was administered to participants between ages 12 and 49 years. The purpose of this article is to present findings of NHANES for youth between ages 12 and 19 years. Associations between cardiorespiratory fitness and demographic characteristics will be reported as well as associations with select self-reported physical activity behaviors.

### METHODS

#### SURVEY DESIGN AND STUDY POPULATION

The NHANES is designed to monitor the health and nutritional status of the US civilian, noninstitutionalized population. The surveys are conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention.\textsuperscript{20} Since 1999, a nationally representative sample has been selected annually using a stratified multistage probability cluster sample design. Data are released in 2-year periods (eg, 1999-2000, 2001-2002). Mexican American and black individuals, adolescents aged 12 to 19 years, persons 60 years and older, low-income white individuals, and pregnant women were oversampled in 1999-2002 to allow for more precise estimates for these groups. This report is based on data from the 1999-2002 NHANES.\textsuperscript{21,22} The 1999-2002 NHANES protocol was approved by the National Center for Health Statistics institutional review board, and written informed consent was obtained from all participants 18 years and older. In addition to the consent provided by parents or guardians, written informed assent was also obtained for adolescents younger than 18 years.

#### SUBJECTS

The NHANES protocol consists of a household interview followed by an examination at a mobile examination center. In 1999-2002, 4902 individuals aged 12 to 19 years were interviewed at home, and of these, 4732 individuals (97\%) were examined at the mobile examination center. Of those, 522 (11\%) were excluded from the fitness test for a variety of reasons, including pregnancy, physical limitations, and cardiovascular and asthma conditions or symptoms.\textsuperscript{23} Of those eligible to participate in the fitness test, 923 (20\%) did not have their fitness level estimated for a variety of reasons, including insufficient time to conduct the test, refusal, equipment problems, prematurely terminated tests because of safety concerns, and insufficient heart rate response to classify fitness level (i.e., the change in heart rate between the 2 exercise stages was less than 8 beats/min).

Complete fitness data on 3287 individuals (69\%) are included in the present analyses. Sex, race/ethnicity, age, body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared), and activity levels of this analytic sample were comparable with the overall sample that was examined in the mobile examination center (Table 1).

### CARDIORESPIRATORY FITNESS TEST

Cardiorespiratory fitness was assessed by a submaximal treadmill exercise test. The treadmill test consisted of a 2-minute warm-up, followed by two 3-minute work stages, and a 2-minute cooldown period. Blood pressure, rating of perceived exertion,\textsuperscript{24} and heart rate were obtained during each of the stages. The Jackson noneexercise test formula was used to predict each participant’s fitness level prior to the treadmill test, based on his or her age, sex, BMI, and self-reported physical activity level.\textsuperscript{25} From this prediction, 1 of the 8 protocols was selected for each participant.\textsuperscript{23} The goal of the test was to elicit a heart rate that is approximately 80\% of age-predicted maximum (220–age) by the end of the second exercise stage.\textsuperscript{23}

The main outcome of the cardiorespiratory fitness test is estimated maximal oxygen uptake ($\overline{V}O_2max$). It was estimated by extrapolation to an expected age-specific maximal heart rate using measured heart rate responses to the two 3-minute exercise stages.\textsuperscript{26} It was assumed that the relationship between heart rate and oxygen consumption is linear during treadmill exercise. Because true $\overline{V}O_2max$ values greater than 75 mL·kg\textsuperscript{-1}·min\textsuperscript{-1} are quite rare, we assumed such values to be overestimates and they were coded as 75 mL·kg\textsuperscript{-1}·min\textsuperscript{-1} in the analysis (n=29). Equipment included a Quinton MedTrack ST65 Treadmill (Quinton, Deerfield, Wis) and a Colin STBP-780 Automatic Blood Pressure Monitor (Colin Medical Instruments Corp, San Antonio, Tex) to measure heart rate and blood pressure. All technicians were trained by exercise physiologists from the Cooper Institute, were monitored twice a year, and participated in an annual retraining session to assure quality control.

### Table 1. Characteristics of Participants Aged 12 to 19 Years Examined at the NHANES MEC in 1999-2002

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Sample Size</th>
<th>% (SE)*</th>
<th>Sample Size</th>
<th>% (SE)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>2361</td>
<td>51.1 (0.9)</td>
<td>1686</td>
<td>52.6 (1.5)</td>
</tr>
<tr>
<td>Race/ethnicity†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic white</td>
<td>1208</td>
<td>60.4 (2.1)</td>
<td>826</td>
<td>59.5 (2.0)</td>
</tr>
<tr>
<td>Non-Hispanic black</td>
<td>1398</td>
<td>14.4 (1.6)</td>
<td>951</td>
<td>14.0 (1.6)</td>
</tr>
<tr>
<td>Mexican American</td>
<td>1767</td>
<td>10.9 (1.4)</td>
<td>1246</td>
<td>11.2 (1.4)</td>
</tr>
<tr>
<td>Age, y, mean</td>
<td>4732</td>
<td>15.5 (0.1)</td>
<td>3287</td>
<td>15.4 (0.1)</td>
</tr>
<tr>
<td>BMI, mean</td>
<td>4642</td>
<td>23.2 (0.1)</td>
<td>3287</td>
<td>23.0 (0.1)</td>
</tr>
<tr>
<td>Moderate physical activity, past 30 d (yes)</td>
<td>4591</td>
<td>61.6 (1.1)</td>
<td>3248</td>
<td>63.7 (1.3)</td>
</tr>
<tr>
<td>Vigorous physical activity, past 30 d (yes)</td>
<td>4596</td>
<td>69.5 (1.1)</td>
<td>3249</td>
<td>72.9 (1.2)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); MEC, mobile examination center; NHANES, National Health and Nutrition Examination Surveys.

*No separate estimates were presented for persons classified as “other,” but they are included in the total population estimates.

†No separate estimates were presented for persons classified as “other,” but they are included in the total population estimates.
FITNESSGRAM Standards for Healthy Fitness Zone.29,30 Males

diate, high) of MVPA and VPA for analyses.
VPA). Participants were categorized into tertiles (low, interme-
tivities with a MET value of 3 or more. MET minutes of moderate to vig-
240 minutes each time, respectively) were coded to 90 and 240,
ration higher than the 99th percentile (90 times per 30 days and
activity. To correct for gross errors, reported frequency and du-
divided by 30 to obtain MET minutes per day for each reported
of times an activity was performed was multiplied by the num-

Physical Activity Variables

Self-reported physical activity variables were dichotomized into
yes or no for activities performed during the last 30 days. The
activities included walking or biking as part of getting to and
from work, school, or errands; moderate-intensity physical ac-
tivities performed for at least 10 minutes that cause light sweat-
ing or slight to moderate increase in breathing or heart rate;
vigorous-intensity physical activities performed for at least 10
minutes that cause heavy sweating or large increases in breath-
ing or heart rate; and physical activities specifically designed
to strengthen muscles, such as lifting weights, push-ups, or sit-
ups. Additionally, participants were asked if their amount of
activity during the past 30 days was more, less, or about the
same as others of the same age and sex.

Sedentary activity questions differed by age group. partici-
pants aged 16 to 19 years reported the amount of time on a typi-
cal day during the past 30 days that they spent sitting and watch-
ing television or videos or using a computer outside of work.
Children aged 12 to 15 years were asked about television view-
ing and computer use/computer games separately, in refer-
ence to the previous day. The 2 questions were summed. Re-
ponses were dichotomized into fewer than 3 hours and 3 or
more hours per day.

Participants were also asked to identify the type, frequency,
and duration of moderate and vigorous physical activities they
participated in during the past 30 days. All reported activities
were assigned a MET (metabolic equivalent unit) (1 MET=3.5 mL
O₂·kg⁻¹·min⁻¹) value based on reported intensity.28 The number
of times an activity was performed was multiplied by the num-
ber of minutes and the MET value. The total MET score was then
divided by 30 to obtain MET minutes per day for each reported
activity. To correct for gross errors, reported frequency and du-
ration higher than the 99th percentile (90 times per 30 days and
90 minutes each time, respectively) were coded to 90 and 240,
respectively, for the analysis. MET minutes of moderate to vig-
orous-intensity physical activity (MVPA) were calculated by totaling
activities with a MET value of 3 or more. MET minutes of vigorous
physical activity (VPA) were calculated by totaling the activities
with a MET value of 6 or more. Participants received a score of
zero if they did not report any individual activity and responded
no to participation in moderate physical activity or VPA during
the past 30 days (n=503 [15.3%] for MVPA; n=824 [25.1%] for
VPA). Participants were categorized into tertiles (low, interme-
rate, high) of MVPA and VPA for analyses.

Participants were classified into 2 fitness levels based on the
FITNESSGRAM Standards for Healthy Fitness Zone.29,30 Males
aged 12 to 19 years with a VO₂max of 42 mL·kg⁻¹·min⁻¹ or higher
were classified as meeting the FITNESSGRAM standards. Girls
aged 12 and 13 years with a VO₂max of 37 and 36 mL·kg⁻¹·min⁻¹,
respectively, were classified as meeting the FITNESSGRAM stan-
dards. Females aged 14 to 19 with a VO₂max of 35 mL·kg⁻¹·min⁻¹
or higher were classified as meeting the FITNESSGRAM stan-
dards.

STATISTICAL ANALYSES

All analyses were conducted separately for males and females.
Means and deciles of estimated VO₂max were calculated for 4
age groups. One-way analyses of variance using estimated VO₂max
as the dependent variable were conducted for demographic,
weight status, and physical activity variables and by tertiles of
MET minutes of physical activity. The trends of VO₂max by ter-
tiles of MET minutes of MVPA and VPA were also tested. Sample
weights were used to account for differential probabilities of
selection, noncoverage, and nonresponse to the examina-
tion.31 Standard errors were calculated using the Taylor series
linearization method. Statistical significance was defined as
α=.05. Paired comparisons were done within each category
when the testing for analysis of variance was significant. The
Bonferroni method was used to adjust for multiple comparis-
ons. Thus, for age group comparisons, α=.008 was used and
for weight status, MVPA, and VPA, α=.017 was used for sig-
nificance level. All statistical analyses were conducted using SAS
for Windows32 and SUDAAN.33

Percentiles for estimated VO₂max are presented in Table 2
by sex and age group. Generally, among males, older par-
ticipants had higher VO₂max values, while in females,
younger participants had higher values.

Estimated VO₂max is presented by demographic groups,
weight status, and FITNESSGRAM categories in Table 3.
Estimated VO₂max was higher in males than females. In
males, estimated VO₂max was significantly lower in 12-
and 13-year-olds than in the other age groups. Males in
the normal weight group had significantly higher esti-
mated VO₂max than those in the at risk for overweight
and overweight groups, and a higher percentage of older males
(aged 14-19 years) than younger males (aged 12-13 years)
met the FITNESSGRAM standards. In females, estimated
VO₂max was significantly lower in older females
(aged 18-19 years) than in younger females (aged 12-13
years). Females in the normal weight group had higher
estimated VO₂max than the females in the at risk for over-
weight and overweight groups. There were no dif-
fences among the age groups for females meeting the
FITNESSGRAM standards.

Table 4 shows the comparison of the estimated VO₂max
among physical activity variable categories. Males who
commuted through walking or biking, participated in
VPA, or did strengthening exercise during the past 30
days were fitter than males who did not report these ac-
tivities. Females who reported walking or biking during
the past 30 days were more fit than females who did not
report walking or biking. Males and females who re-
ported fewer than 3 hours of television, video, or com-
puter use per day had higher fitness levels compared with
those who participated in 3 or more hours. Those who
considered themselves to be more active than their peers

©2006 American Medical Association. All rights reserved.
Table 2. Deciles of Estimated $\dot{V}O_{2max}$ by Sex and Age Groups

<table>
<thead>
<tr>
<th>Sample Size</th>
<th>Decile, Mean $\dot{V}O_{2max}$ (95% Confidence Interval), mL·kg$^{-1}$·min$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
</tr>
<tr>
<td>Ages 12-13 y</td>
<td>393</td>
</tr>
<tr>
<td>Ages 14-15 y</td>
<td>424</td>
</tr>
<tr>
<td>Ages 16-17 y</td>
<td>486</td>
</tr>
<tr>
<td>Ages 18-19 y</td>
<td>383</td>
</tr>
<tr>
<td>Females</td>
<td></td>
</tr>
<tr>
<td>Ages 12-13 y</td>
<td>465</td>
</tr>
<tr>
<td>Ages 14-15 y</td>
<td>434</td>
</tr>
<tr>
<td>Ages 16-17 y</td>
<td>379</td>
</tr>
<tr>
<td>Ages 18-19 y</td>
<td>323</td>
</tr>
</tbody>
</table>

Table 3. Estimated $\dot{V}O_{2max}$ by Age, Race/Ethnicity, Weight Status, and Percentage Meeting Fitness Standards for Males and Females Aged 12 to 19 Years

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sample Size</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\dot{V}O_{2max}$ Mean (SE), mL·kg$^{-1}$·min$^{-1}$</td>
<td>$\dot{V}O_{2max}$ Mean (SE), mL·kg$^{-1}$·min$^{-1}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$P$ Value</td>
<td>$P$ Value</td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-13</td>
<td>1686</td>
<td>46.6 (0.4)</td>
<td>1601</td>
</tr>
<tr>
<td>14-15</td>
<td>393</td>
<td>44.6 (0.7)</td>
<td>465</td>
</tr>
<tr>
<td>16-17</td>
<td>424</td>
<td>47.1 (0.8)</td>
<td>434</td>
</tr>
<tr>
<td>18-19</td>
<td>486</td>
<td>46.9 (0.6)</td>
<td>379</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic white</td>
<td>436</td>
<td>46.7 (0.6)</td>
<td>390</td>
</tr>
<tr>
<td>Non-Hispanic black</td>
<td>486</td>
<td>46.9 (0.5)</td>
<td>465</td>
</tr>
<tr>
<td>Mexican American</td>
<td>635</td>
<td>46.1 (0.5)</td>
<td>611</td>
</tr>
<tr>
<td>Weight status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>1141</td>
<td>48.2 (0.5)</td>
<td>1010</td>
</tr>
<tr>
<td>At risk for overweight</td>
<td>249</td>
<td>42.5 (0.6)</td>
<td>278</td>
</tr>
<tr>
<td>Overweight</td>
<td>296</td>
<td>41.6 (1.0)</td>
<td>313</td>
</tr>
<tr>
<td>Percentage meeting fitness standards</td>
<td>Yes/Total No.</td>
<td>% (SE)</td>
<td>Yes/Total No.</td>
</tr>
<tr>
<td>Ages 12-13 y</td>
<td>232/393</td>
<td>55.3 (2.5)</td>
<td>284/465</td>
</tr>
<tr>
<td>Ages 14-15 y</td>
<td>287/424</td>
<td>70.0 (3.6)</td>
<td>297/434</td>
</tr>
<tr>
<td>Ages 16-17 y</td>
<td>330/486</td>
<td>70.1 (2.7)</td>
<td>256/379</td>
</tr>
<tr>
<td>Ages 18-19 y</td>
<td>256/383</td>
<td>71.7 (2.9)</td>
<td>189/323</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); $\dot{V}O_{2max}$, maximal oxygen uptake.

Females

1010 39.6 (0.3)

than 85th percentile of BMI for age = normal weight; 85th to less than 95th percentile of BMI for age = at risk for overweight; 95th percentile or higher of BMI for age = overweight.

were more fit than those who considered themselves to be less active or about the same as others. For both males and females, there was a statistically significant positive trend for higher levels of fitness with increasing tertiles of both MVPA and VPA.

The NHANES is conducted in nationally representative samples of American youth, and in the 1999-2002 survey cycle, the protocol included a submaximal tread-
One method for interpreting physical fitness levels of contemporary American youth is to apply criterion-referenced standards that are well validated. As such, the information that may bear on this issue. As shown by the data in Table 3, weight status was associated with fitness, with overweight and at-risk-for-overweight males and females showing lower cardiorespiratory fitness than their normal-weight peers. This suggests that population-level increases in the prevalence of obesity are likely to be associated with decreased cardiorespiratory fitness. This would be expected when fitness is measured with a weight-bearing task such as treadmill walking or running, because greater weight requires more energy to be expended at any specified speed of movement. Nonetheless, a clear demonstration of a secular decline in physical fitness in American youth must await the result of future surveys using methods comparable with those used in this and/or earlier surveys.

One method for interpreting physical fitness levels of youth is to apply criterion-referenced standards that are.

**Table 4. Estimated VO_{2max} by Physical Activity Categories for Males and Females Aged 12 to 19 Years**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committed by walking/biking, past 30 d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>816 47.6 (0.5)</td>
<td>742 39.3 (0.4)</td>
</tr>
<tr>
<td>No</td>
<td>848 45.7 (0.5)</td>
<td>842 38.2 (0.3)</td>
</tr>
<tr>
<td>Moderate physical activity, past 30 d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>938 46.7 (0.6)</td>
<td>953 38.8 (0.4)</td>
</tr>
<tr>
<td>No</td>
<td>726 46.4 (0.5)</td>
<td>631 38.3 (0.4)</td>
</tr>
<tr>
<td>VPA, past 30 d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1282 47.1 (0.5)</td>
<td>959 39.0 (0.4)</td>
</tr>
<tr>
<td>No</td>
<td>383 44.7 (0.6)</td>
<td>625 37.9 (0.3)</td>
</tr>
<tr>
<td>Strength exercise, past 30 d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1146 47.1 (0.5)</td>
<td>825 39.2 (0.4)</td>
</tr>
<tr>
<td>No</td>
<td>518 45.4 (0.7)</td>
<td>758 38.1 (0.4)</td>
</tr>
<tr>
<td>Television/video/computer use, h/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;3</td>
<td>751 47.4 (0.7)</td>
<td>775 39.5 (0.3)</td>
</tr>
<tr>
<td>≥3</td>
<td>914 45.8 (0.4)</td>
<td>808 37.8 (0.5)</td>
</tr>
<tr>
<td>Compared with others</td>
<td></td>
<td></td>
</tr>
<tr>
<td>More active</td>
<td>567 49.2 (0.5)</td>
<td>429 40.1 (0.4)</td>
</tr>
<tr>
<td>About the same</td>
<td>938 45.7 (0.5)</td>
<td>866 38.6 (0.4)</td>
</tr>
<tr>
<td>Less active</td>
<td>158 41.9 (1.3)</td>
<td>289 36.5 (0.6)</td>
</tr>
<tr>
<td>Tertiles of MET-min/d MVPA activities†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>555 44.3 (0.5)</td>
<td>529 37.6 (0.4)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>557 46.6 (0.7)</td>
<td>527 38.4 (0.6)</td>
</tr>
<tr>
<td>High</td>
<td>553 48.6 (0.4)</td>
<td>528 39.7 (0.4)</td>
</tr>
<tr>
<td>Tertiles of MET-min/d VPA activities§</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>555 44.0 (0.7)</td>
<td>527 38.1 (0.4)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>555 46.9 (0.5)</td>
<td>530 37.9 (0.5)</td>
</tr>
<tr>
<td>High</td>
<td>555 48.3 (0.6)</td>
<td>527 39.8 (0.4)</td>
</tr>
</tbody>
</table>

Abbreviations: MET, metabolic equivalent unit; MVPA, moderate to vigorous activity; VO_{2max}, maximal oxygen uptake; VPA, vigorous physical activity.

*P values refer to sex-specific comparisons within each activity category using 1-way analysis of variance.

†P values refer to sex-specific comparisons within each activity category using 1-way analysis of variance.

‡P values refer to sex-specific comparisons within each activity category using 1-way analysis of variance.

§P values refer to sex-specific comparisons within each activity category using 1-way analysis of variance.

©2006 American Medical Association. All rights reserved.
linked to functional and/or health outcomes. Such an approach is used by FITNESSGRAM, a fitness testing program that has been used by more than 18,000 schools and school districts nationally. The criterion-referenced standards used by FITNESSGRAM were developed by an expert panel, and for cardiorespiratory fitness, the standards for maximal oxygen uptakes are 42 mL·kg−1·min−1 for males and 35 to 37 mL·kg−1·min−1 (depending on age) for females.29 When these standards are applied to the group measured in this study, approximately 65% of both males and females meet the standards. This indicates that roughly one third of US youth aged 12 to 19 years fail to meet the levels of cardiorespiratory fitness deemed appropriate by experts.

The findings presented in this report confirm the frequently observed sex difference in cardiorespiratory endurance. Mean estimated VO2max was approximately 17% lower in girls than boys in the overall sample, and the sex difference increased with increasing age from about 11% in 12- and 13-year-olds to more than 21% in 18- and 19-year-olds. These differences are comparable with those reported in previous surveys.14,30 The widening sex difference with increasing age was due to countervailing age-related differences in the 2 sexes. Fitness increased with age in males but decreased with age in females, and these changes were statistically significant in both sexes. This may be explained by physical developmental factors, such as sex-related changes in lean weight and fat weight during puberty.31 However, some studies have shown that the sex difference in physical activity levels widens during adolescence, so it may be that rapidly declining physical activity in females may partially explain the age-related trends in physical fitness.41,42

In this study, fitness did not differ across the 3 race/ethnicity groups observed. Most previous national surveys of fitness in children and youth did not report data for race/ethnicity subgroups.10,12,13 However, 1 national survey in the 1960s did find higher cardiorespiratory fitness in black youth than white youth.14 That observation is inconsistent with the findings of most studies using smaller samples that were not nationally representative. Several of these studies have observed higher fitness in white than black adolescents.2,33 The present study is unique because the sampling protocol ensured that nationally representative samples of non-Hispanic white, non-Hispanic black, and Mexican American males and females were included. The findings provide no indication that cardiorespiratory fitness varied across those 3 population subgroups in 1999-2002.

In general, youth who reported higher levels of physical activity had higher levels of cardiorespiratory fitness. Those who reported participating in VPA during the past 30 days and those who were in the upper tertile of MET minutes per day of MVPA and VPA were more fit than other participants. Although these findings suggest that higher levels of physical activity result in higher levels of fitness, the data are cross-sectional and the direction of causality cannot be determined. It may be that young people who have higher cardiorespiratory fitness find it easier or more enjoyable to participate in physical activity.

The only exception to the activity-fitness pattern was for moderate physical activity in the past 30 days; those who reported participating in moderate physical activity during the past 30 days did not have higher fitness levels than those who did not report such activity. This may be due to inaccuracies in the classification and reporting of moderate activity by children and youth or to the fact that VPA explains more of the variance in fitness than moderate activity.44 In addition to a positive relationship between physical activity and fitness, we also observed a negative relationship between sedentary activity and fitness. Participants who reported 3 or more hours per day of television, video, and computer use had lower levels of fitness than those who reported less than 3 hours of these activities. This finding differs from previous studies that found no significant relationship between television watching and fitness.45,46 The inclusion of other electronic media, in addition to television, in the present study may provide a more accurate estimate of the amount of time that children and youth spend in sedentary activity.

The findings of this study suggest that one third of youth aged 12 to 19 years in the United States has low levels of cardiorespiratory fitness. Low cardiorespiratory fitness, a strong and independent risk factor for cardiovascular disease,47,48 is known to track from adolescence to adulthood.49,50 Further, it has been shown that low cardiorespiratory fitness in adolescence predicts adult body fatness,51 large-artery stiffness,52 poor lipid profiles,53,54 and low physical activity levels.55 Accordingly, because highly active youth tend to manifest higher levels of cardiorespiratory fitness, several expert panels have recommended that physicians counsel pediatric and adolescent patients and their parents about the importance of meeting current physical activity guidelines.19,56,57 Identifying youth who are at elevated risk for low cardiovascular fitness is important because fitness testing is impractical in most clinical settings. The findings of this study suggest that youth who have high BMI, low levels of physical activity, and high levels of sedentary behavior are likely to have low cardiorespiratory fitness.

Strengths of this study include the large sample size, the racial and ethnic diversity of the participants, and the use of a standardized testing protocol. The use of a submaximal exercise test for estimating VO2max is a potential weakness of this study, because submaximal tests are less accurate than maximal exercise tests. However, maximal exercise tests are considered impractical for use in population-based studies. Another potential limitation is the response rate of 69%; however, as demonstrated in Table 1, youth included in our study sample were demographically comparable with the total sample examined in the mobile examination center.

CONCLUSIONS

In conclusion, estimated VO2max (mL·kg−1·min−1) was higher in males than females and lower in overweight than normal weight youth but not different across the 3 race/ethnic groups observed (non-Hispanic black, Mexican American, non-Hispanic white). More physically active youth tended to manifest higher fitness levels than those reporting less activity. Approximately one third of males
and females aged 12 to 19 years failed to meet current standards for acceptable cardiorespiratory endurance. This represents a significant public health problem because low physical fitness during adolescence tends to track into adulthood, and low-fit adults are at substantially increased risk for chronic disease morbidity and mortality.

Accepted for Publication: May 26, 2006.

Correspondence: Russell R. Pate, PhD, Department of Exercise Science, University of South Carolina, 921 Assembly St, Columbia, SC 29208 (rpat@gwm.sc.edu).

Author Contributions: Dr Pate had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Pate, Wang, Dowda, and O'Neill. Acquisition of data: Wang, Dowda, and Farrell. Analysis and interpretation of data: Pate, Wang, Dowda, Farrell, and O'Neill. Drafting of the manuscript: Pate, Wang, Dowda, Farrell, and O'Neill. Critical revision of the manuscript for important intellectual content: Wang, Dowda, and O'Neill. Statistical analysis: Wang and Dowda. Administrative, technical, and material support: Farrell and O'Neill. Study supervision: Pate and Farrell.

Funding/Support: This study was funded by grant 5RO1HL057775 from the National Heart, Lung, and Blood Institute (Dr Pate) and grant 5R01HD043125 from the National Institute of Child Health and Human Development (Dr Pate).

Acknowledgment: We thank Gaye Groover Christmas, MPH, and Felipe Lobelo, MD, for assistance in the development of this article.

REFERENCES


**Announcement**

**Trial Registration Required.** In concert with the International Committee of Medical Journal Editors (ICMJE), Archives of Pediatrics and Adolescent Medicine will require, as a condition of consideration for publication, registration of all trials in a public trials registry (such as http://ClinicalTrials.gov). Trials must be registered at or before the onset of patient enrollment. This policy applies to any clinical trial starting enrollment after July 1, 2005. For trials that began enrollment before this date, registration will be required by September 13, 2005, before considering the trial for publication. The trial registration number should be supplied at the time of submission.

For details about this new policy, and for information on how the ICMJE defines a clinical trial, see the editorials by DeAngelis et al in the September 8, 2004 (2004;292:1363-1364) and June 15, 2005 (2005;293:2927-2929) issues of JAMA. Also see the Instructions to Authors on our Web site: www.archpediatrics.com.