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 (VO₂max) determined by a submaximal treadmill exercise test.

Results: Estimated VO₂max (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 VO₂max 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.

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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.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.

**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.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.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.

**METHODS**

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,24 and heart rate were obtained during each of the stages. The Jackson nonexercise 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.25 From this prediction, 1 of the 8 protocols was selected for each participant.21 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.23

The main outcome of the cardiorespiratory fitness test is estimated maximal oxygen uptake (\(\text{VO}_{2\text{max}}\)). 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.26 It was assumed that the relationship between heart rate and oxygen consumption is linear during treadmill exercise. Because true \(\text{VO}_{2\text{max}}\) values greater than 75 mL·kg\(^{-1}\)·min\(^{-1}\) are quite rare, we assumed such values to be overestimates and they were coded as 75 mL·kg\(^{-1}\)·min\(^{-1}\) 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></td>
<td></td>
<td></td>
<td></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.

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

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Participants were placed in 4 age groups: 12 to 13, 14 to 15, 16 to 17, and 18 to 19 years of age. Self-reported information on race and ethnicity was categorized as non-Hispanic white, non-Hispanic black, Mexican American, and other. Because of the small sample size of the “other” group, no separate estimates were presented for persons classified as “other,” but they are included in the total population estimates. Measured weight and height were used to calculate BMI. The 2000 Centers for Disease Control and Prevention Growth Charts for the United States were used to define normal weight, at risk for overweight, and overweight. Normal weight is defined as less than the 85th percentile of BMI for age, at risk for overweight is defined as at or higher than the 85th percentile but less than the 95th percentile of BMI for age, and overweight is defined as at or higher than the 95th percentile of BMI for age.

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 activities performed for at least 10 minutes that cause light sweating 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 breathing 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. Participants aged 16 to 19 years reported the amount of time on a typical day during the past 30 days that they spent sitting and watching television or videos or using a computer outside of work. Children aged 12 to 15 years were asked about television viewing and computer use/computer games separately, in reference to the previous day. The 2 questions were summed. Responses 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. The number of times an activity was performed was multiplied by the number 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 duration higher than the 99th percentile (90 times per 30 days and 240 minutes each time, respectively) were coded to 90 and 240, respectively, for the analysis. MET minutes of moderate to vigorous 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, intermediate, high) of MVPA and VPA for analyses.

Participants were classified into 2 fitness levels based on the FITNESSGRAM standards. Girls aged 12 to 15 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 standards. Females aged 14 to 19 with a VO₂max of 35 mL·kg⁻¹·min⁻¹ or higher were classified as meeting the FITNESSGRAM standards.
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-
Table 4. Estimated \( \dot{V}O_{2\text{max}} \) 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></td>
<td>Sample Size</td>
<td>( \dot{V}O_{2\text{max}}, \text{Mean (SE)}) mL·kg(^{-1})·min(^{-1})</td>
</tr>
<tr>
<td>Commuted by walking/biking, past 30 d</td>
<td>816</td>
<td>47.6 (0.5)</td>
</tr>
<tr>
<td>No</td>
<td>848</td>
<td>45.7 (0.5)</td>
</tr>
<tr>
<td>Moderate physical activity, past 30 d</td>
<td>938</td>
<td>46.7 (0.6)</td>
</tr>
<tr>
<td>No</td>
<td>726</td>
<td>46.4 (0.5)</td>
</tr>
<tr>
<td>VPA, past 30 d</td>
<td>1282</td>
<td>47.1 (0.5)</td>
</tr>
<tr>
<td>No</td>
<td>383</td>
<td>44.7 (0.6)</td>
</tr>
<tr>
<td>Strength exercise, past 30 d</td>
<td>1146</td>
<td>47.0 (0.5)</td>
</tr>
<tr>
<td>Yes</td>
<td>518</td>
<td>45.4 (0.7)</td>
</tr>
<tr>
<td>Compared with others</td>
<td></td>
<td></td>
</tr>
<tr>
<td>More active</td>
<td>567</td>
<td>49.2 (0.5)</td>
</tr>
<tr>
<td>About the same</td>
<td>938</td>
<td>45.7 (0.5)</td>
</tr>
<tr>
<td>Less active</td>
<td>158</td>
<td>41.9 (1.5)</td>
</tr>
<tr>
<td>Tertiles of MET-min/d MVPA activities†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>555</td>
<td>44.3 (0.5)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>557</td>
<td>46.6 (0.7)</td>
</tr>
<tr>
<td>High</td>
<td>553</td>
<td>48.6 (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</td>
<td>44.4 (0.7)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>555</td>
<td>46.9 (0.5)</td>
</tr>
<tr>
<td>High</td>
<td>555</td>
<td>48.3 (0.6)</td>
</tr>
</tbody>
</table>

Abbreviations: MET, metabolic equivalent unit; MVPA, moderate to vigorous activity; \( \dot{V}O_{2\text{max}} \), maximal oxygen uptake; VPA, vigorous physical activity.

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

†For females, low = 0 to 48, intermediate = 49 to 247.5, and high = 248 to 10573 MET-min/d. For males, low = 0 to 139, intermediate = 139.2 to 510, and high = 510.5 to 8904 MET-min/d.

‡P values refer to sex-specific trend testing within each activity category.

§For females, low = 0 to 3.7, intermediate = 4 to 19.9, and high = 170 to 10373.5 MET-min/d. For males, low = 0 to 86.7, intermediate = 89 to 417, and high = 420 to 8904 MET-min/d.

mill exercise test. An accepted criterion measure of cardiorespiratory fitness is maximal oxygen consumption, \( \dot{V}O_{2\text{max}} \), measured by gas exchange during performance of exhaustive exercise. The submaximal treadmill test used in NHANES involves applying the slope of the heart rate response to submaximal exercise in estimating \( \dot{V}O_{2\text{max}} \), a procedure that has been well validated. As such, the fitness of cardiorespiratory fitness levels is important because it provides a basis for monitoring future trends in physical fitness in the population of 12- to 19-year-old youth in the United States. In addition, these data provide population norms against which individuals and groups of youth can be compared.

Table 4. Estimated \( \dot{V}O_{2\text{max}} \) by Physical Activity Categories for Males and Females Aged 12 to 19 Years

National population-based surveys in the United States have monitored body weight status in youth since 1963. Recent surveys have demonstrated a marked increase in the prevalence of obesity in young people. In addition, many have suggested that physical fitness has declined in American youth during this same period. Physical fitness was surveyed in representative samples of American youth on several occasions between the late 1950s and mid 1980s. Unfortunately, the procedures used to measure physical fitness varied from survey to survey, and none of the previous national surveys used controlled testing procedures such as those used in the present survey. Consequently, it is not possible to determine whether there have been population-level changes in fitness in American youth during the past several decades. However, the present study includes some 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
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. 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 VO$_{2\text{max}}$ 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. 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. 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.

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. However, 1 national survey in the 1960s did find higher cardiorespiratory fitness in black youth than white youth. 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. 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. 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. 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, is known to track from adolescence to adulthood. Further, it has been shown that low cardiorespiratory fitness in adolescence predicts adult body fatness, large-artery stiffness, poor lipid profiles, and low physical activity levels. 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. 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 VO$_{2\text{max}}$ 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.

In conclusion, estimated VO$_{2\text{max}}$ (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.

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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.

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REFERENCES


