

Original Contribution

Cardiorespiratory Fitness Levels Among US Adults 20–49 Years of Age: Findings From the 1999–2004 National Health and Nutrition Examination Survey

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Data from the 1999–2004 National Health and Nutrition Examination Survey were used to describe the distribution of cardiorespiratory fitness and its association with obesity and leisure-time physical activity (LTPA) for adults 20–49 years of age without physical limitations or indications of cardiovascular disease. A sample of 7,437 adults aged 20–49 years were examined at a mobile examination center. Of 4,860 eligible for a submaximal treadmill test, 3,250 completed the test and were included in the analysis. The mean maximal oxygen uptake ($\dot{V}O_{2\max}$) was estimated as 44.5, 42.8, and 42.2 mL/kg/minute for men 20–29, 30–39, and 40–49 years of age, respectively. For women, it was 36.5, 35.4, and 34.4 mL/kg/minute for the corresponding age groups. Non-Hispanic black women had lower fitness levels than did non-Hispanic white and Mexican-American women. Regardless of gender or race/ethnicity, people who were obese had a significantly lower estimated maximal oxygen uptake than did nonobese adults. Furthermore, a positive association between fitness level and LTPA participation was observed for both men and women. These results can be used to track future population assessments and to evaluate interventions. The differences in fitness status among population subgroups and by obesity status or LTPA can also be used to develop health policies and targeted educational campaigns.

body mass index; cardiovascular diseases; chronic disease; exercise; nutrition surveys; physical fitness; reference values

Abbreviations: LTPA, leisure-time physical activity; MET, metabolic equivalent; NHANES, National Health and Nutrition Examination Surveys; $\dot{V}O_{2\max}$, maximal oxygen uptake.

As stated in the Surgeon General's report on physical activity and health in 1996, higher cardiorespiratory fitness decreases overall mortality rates and morbidity and mortality due to various chronic diseases in a dose-response fashion (1). These associations have been demonstrated to be largely independent from other major risk factors (2–7). Despite the accumulating evidence supporting the important health benefits of cardiorespiratory fitness, data on the population distribution of fitness levels are very limited for US adults. Since the early 1970s, data from the National Health and Nutrition Examination Surveys (NHANES) have been used to monitor the health status of the nation. In 1999, a cardiorespiratory fitness component was added to the NHANES to provide an objective assessment of

fitness level by using a submaximal treadmill test. The distribution of cardiorespiratory fitness, as indicated by estimated maximal oxygen uptake ($\dot{V}O_{2\max}$), for adults aged 20–49 years from the 1999–2002 NHANES has been previously reported by Duncan et al. (8). The present report updates those estimates with additional NHANES data from 2003 to 2004. Six years of data yield more stable and precise estimates of the $\dot{V}O_{2\max}$ because data were collected from a greater number of locations and because sample sizes were larger. In addition to the mean $\dot{V}O_{2\max}$ for the population overall, the current report further provides detailed percentile estimates by age, gender, and selected race/ethnicity subgroups, as well as its association with body mass index and leisure-time physical activity

Table 1. Characteristics of Participants by Eligibility for the Cardiorespiratory Fitness Component, National Health and Nutrition Examination Surveys, 1999–2004^a

	Eligible for the Test		Not Eligible for the Test
	$\dot{V}O_2\text{max}$ Estimated	No $\dot{V}O_2\text{max}$ Estimated	
Sample size, no.	3,250	1,610	2,577
Female, %	47.7 (1.2)	51.0 (1.3)	55.8 (1.2) ^b
Age, years	33.9 (0.2)	33.8 (0.3)	37.4 (0.3) ^b
Race/ethnicity, %			
Non-Hispanic white	70.9 (1.5) ^c	57.8 (2.5)	68.5 (2.0)
Non-Hispanic black	10.5 (1.0) ^c	14.6 (1.4)	13.6 (1.3) ^b
Mexican American	9.5 (1.0) ^c	12.9 (1.2)	7.5 (1.0) ^b
Educational level less than high school, %	14.1 (0.8) ^c	22.1 (1.3)	20.8 (1.1) ^b
Poverty income ratio <1.3, %	17.5 (1.2) ^c	27.3 (1.9)	29.5 (1.7) ^b
Current smoker, %	27.1 (1.2) ^c	31.4 (1.6)	33.6 (1.3) ^b
No leisure physical activity reported, %	26.3 (1.1) ^c	33.5 (1.6)	42.0 (1.4) ^b
Body mass index, kg/m ²	27.0 (0.1)	27.0 (0.2)	29.7 (0.2) ^b
Resting heart rate, beats/minute	71.3 (0.3) ^c	73.1 (0.4)	77.0 (0.4) ^b
Resting systolic blood pressure, mm Hg	115.3 (0.3)	116.2 (0.4)	119.7 (0.5) ^b
Resting diastolic blood pressure, mm Hg	71.2 (0.2)	71.8 (0.4)	74.0 (0.4) ^b
Total cholesterol, mg/dL	193.4 (0.8)	195.4 (1.5)	203.2 (1.2) ^b

Abbreviations: SE, standard error; $\dot{V}O_2\text{max}$, maximal oxygen uptake.^a Values are expressed as percent (SE) or mean (SE) except as noted otherwise.^b Significantly different from people who are eligible for the test at $P < 0.05$.^c Significantly different from “eligible but no $\dot{V}O_2\text{max}$ estimated” group at $P < 0.05$.

within the context of the most current physical activity guidelines (9).

MATERIALS AND METHODS

Survey design and study population

The NHANES are conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention to monitor the health and nutritional status of the United States. The design for the 1999–2004 NHANES is a stratified multistage probability sample of the civilian non-institutionalized population of the United States. Mexican Americans, blacks, adolescents 12–19 years of age, persons 60 years or older, low income whites, and pregnant women were oversampled to allow for more precise estimates for these groups. The survey consisted of a household interview followed by a physical examination at a mobile examination center. A cardiorespiratory fitness test component was included as part of the physical examination for participants aged 12–49 years (10).

From 1999 through 2004, 7,437 individuals aged 20–49 years were examined at the mobile examination center. Among them, 2,577 were not eligible for the fitness test because of one or more of the following reasons: pregnancy of more than 12 weeks ($n = 595$); physical limitations that

would prevent them from using the treadmill ($n = 792$); history of cardiovascular diseases or cardiovascular conditions or symptoms ($n = 723$); asthma symptoms ($n = 250$); other lung or breathing conditions or symptoms ($n = 515$); use of β -blockers, antiarrhythmics, calcium channel blockers, nitrates, or digitalis ($n = 231$); or other reasons ($n = 192$). Selected characteristics of eligible and noneligible participants are shown in Table 1. Results in this report apply to the US population with a set of characteristics as defined by the eligibility criteria. That is, the population of inference is the US civilian noninstitutional population who are aged 20–49 years and who have neither physical limitations nor history of cardiovascular diseases and related symptoms.

Among individuals who were eligible to participate in the fitness test, 1,610 did not have their fitness level estimated. For 816 eligible participants, the following reasons accounted for the missing fitness data: insufficient time to conduct the test ($n = 540$), participant refusal ($n = 106$), equipment problems ($n = 67$), and otherwise unclassifiable reasons ($n = 103$). For 720 eligible participants, $\dot{V}O_2\text{max}$ was not estimated because the test was terminated prematurely. The most common reason for premature termination was a heart rate exceeding the predetermined limit ($n = 417$). Other safety concerns arising during the test, such as inability of the participant to walk on the treadmill without

gripping the handrails ($n = 55$), an abnormal blood pressure or heart rate response ($n = 48$), and the occurrence of excess fatigue, discomfort, or distress such as leg pain, cramping, or dizziness, also resulted in an early termination of the fitness test ($n = 89$). Finally, data from 74 eligible and tested participants were excluded from analysis because the change in heart rate between the two 3-minute exercise stages was less than 8 beats per minute, indicating an insufficient heart rate response to classify fitness level. Therefore, 3,250 individuals with an estimated $\dot{V}O_{2\max}$ are included in the analyses.

The 1999–2004 NHANES protocol was approved by the National Center for Health Statistics institutional review board, and written informed consent was obtained from all participants.

Cardiorespiratory fitness test

Cardiorespiratory fitness was assessed by a submaximal treadmill exercise test. Participants were assigned to 1 of 8 treadmill test protocols on the basis of their expected $\dot{V}O_{2\max}$, which was predicted from gender, age, body mass index, and self-reported level of physical activity by using the formula developed by Jackson et al. (11). Each protocol included a 2-minute warm-up, two 3-minute exercise stages, and a 2-minute cool-down period (10). The goal of each protocol was to elicit a heart rate that was approximately 80% of the age-predicted maximum ($220 - \text{age}$) by the end of the second exercise stage.

The heart rate was monitored continuously via 4 electrodes connected to the trunk and abdomen of the participant, and it was recorded at the end of warm-up, each exercise stage, and each minute of recovery. Blood pressure was measured at the end of each stage by an STBP-780 automated sphygmomanometer (Colin Medical Instruments Corporation, San Antonio, Texas). At the end of warm-up and each exercise stage, participants were asked to rate their perceived exertion using a 6- to 20-point Borg scale (12).

$\dot{V}O_{2\max}$ (mL/kg/minute) was estimated by extrapolation to an expected age-specific maximal heart rate by using measured heart rate responses to the two 3-minute exercise stages (13). It was assumed that the relation between heart rate and oxygen consumption is linear during treadmill exercise (14). An estimated $\dot{V}O_{2\max}$ greater than 75 mL/kg/minute was coded as 75 mL/kg/minute in the analysis ($n = 11$).

Covariates

Self-reported information on race and ethnicity was categorized as non-Hispanic white, non-Hispanic black, and Mexican American. Persons not classified into one of these groups were included in total population estimates but are not presented separately. Participants were asked to recall the type, frequency, duration, and intensity of leisure-time physical activities (LTPAs) that they engaged in for at least 10 minutes during the 30 days preceding their interview. Reported frequencies and durations above the 99th percentile (60 times per 30 days and 300 minutes each time, respectively) were coded to 60 and 300, respectively, for the analysis. A metabolic equivalent (MET; 1 MET = 3.5 mL of

oxygen uptake per kg per minute) score was assigned to each activity to represent a standardized energy cost for the reported activity based on self-reported intensity (15). The MET score of each activity was multiplied by the reported frequency and duration and then summed and divided by 30 before being multiplied by 7 to obtain the total MET-minutes per week. For the analysis, participants were grouped into 4 LTPA categories: no LTPA reported, low ($0 < 500$ MET-minutes/week), moderate ($500 < 1,000$ MET-minutes/week), or high ($\geq 1,000$ MET-minutes/week). The cutpoints were chosen on the basis of the 2008 *Physical Activity Guidelines for Americans* recommendations (9). Measured weight and height were used to calculate body mass index (weight (kg)/height (m)²). On the basis of their body mass index, participants were classified as normal weight ($18.5 < 25$ kg/m²), overweight ($25 < 30$ kg/m²), or obese (≥ 30 kg/m²) (16). Because of limited sample size ($n = 75$), underweight participants (body mass index < 18.5 kg/m²) were excluded from analyses using body mass index categories.

Statistical analysis

Distribution of estimated $\dot{V}O_{2\max}$ was examined by gender, age, and race/ethnicity group, as well as by body mass index and LTPA category. The trends of $\dot{V}O_{2\max}$ by decades of age were tested separately for the total sample and by race/ethnicity groups by using logistic regression with age decades (20–29, 30–39, and 40–49 years) included as an ordinal variable. The trends of $\dot{V}O_{2\max}$ by LTPA levels were tested for men and women separately by using logistic regression. Sample weights were used to account for differential probabilities of selection, noncoverage, and nonresponse to the examination (17). Standard errors were calculated by the Taylor series linearization method. Statistical hypotheses were tested univariately at the 0.05 level by using a t statistic. To adjust for multiple comparisons when 3 race/ethnicity groups, 3 body mass index categories, or 4 LTPA groups were compared, we used the Bonferroni method. All statistical analyses were conducted with SAS for Windows (SAS Institute, Inc., Cary, North Carolina) and SUDAAN (SUDAAN Statistical Software Center, Research Triangle Park, North Carolina) software.

Nonresponse assessment

In the 1999–2004 NHANES, 4,860 participants aged 20–49 years were eligible for the cardiorespiratory fitness component. For the various reasons discussed above, 1,610 (33%) did not have their $\dot{V}O_{2\max}$ estimated. Assessment was performed to examine potential nonresponse bias. Table 1 describes the characteristics of the eligible participants that did and did not have their $\dot{V}O_{2\max}$ estimated along with a description of examined NHANES participants aged 20–49 years who were not eligible for the cardiorespiratory fitness component. Compared with those who were eligible and had $\dot{V}O_{2\max}$ estimated, eligible individuals missing $\dot{V}O_{2\max}$ had a larger proportion of non-Hispanic blacks and Mexican Americans and a smaller proportion of non-Hispanic whites, and they tended to have

Table 2. Mean and Selected Percentiles^a of Estimated $\dot{V}O_2\text{max}$ (mL/kg/minute) by Age and Race/Ethnicity Groups for Men 20–49 Years of Age, National Health and Nutrition Examination Surveys, 1999–2004

	No.	Mean (SE)	P Value ^b	Percentile					
				20th	95% Confidence Interval	50th	95% Confidence Interval	80th	95% Confidence Interval
Total ^c									
All ages	1,707	43.2 (0.3)		36.8	36.2, 37.3	42.3	41.6, 42.9	48.5	47.9, 49.5
20–29 years	675	44.5 (0.4)		37.9	37.3, 38.6	43.8	42.9, 44.5	50.2	48.9, 51.4
30–39 years	574	42.8 (0.5)	<0.05	36.4	35.5, 37.3	41.8	40.7, 43.1	48.0	47.1, 49.3
40–49 years	458	42.2 (0.6)		35.5	34.7, 37.0	40.9	39.7, 41.8	47.2	46.0, 49.1
Non-Hispanic white									
All ages	803	43.4 (0.4)		37.2	36.5, 37.6	42.4	41.5, 43.2	48.8	47.7, 50.0
20–29 years	288	44.5 (0.5)		37.9	37.3, 39.2	43.8	42.6, 44.5	50.4	48.6, 51.7
30–39 years	288	43.4 (0.6) ^d	<0.05	36.9	36.1, 38.0	42.1	41.0, 43.7	48.8	47.2, 50.3
40–49 years	227	42.4 (0.7)		36.1	34.8, 37.3	41.0	39.7, 42.5	47.2	45.7, 49.5
Non-Hispanic black									
All ages	332	42.7 (0.5)		35.8	35.2, 36.3	40.7	39.8, 42.2	48.1	47.0, 49.4
20–29 years	138	45.7 (0.9)		37.3	36.0, 39.5	44.4	42.2, 45.8	53.6	49.1, 57.0
30–39 years	105	40.7 (0.7) ^e	<0.001	34.7	33.2, 35.9	38.6	37.2, 42.2	46.3	45.2, 47.8
40–49 years	89	40.3 (0.6)		35.3	34.2, 35.9	39.1	37.6, 40.4	45.6	42.3, 48.1
Mexican American									
All ages	443	43.6 (0.5)		36.0	35.1, 37.2	42.2	40.8, 43.6	49.8	48.1, 51.4
20–29 years	193	44.6 (0.8)		36.9	35.8, 38.7	43.7	41.7, 45.2	50.4	48.3, 53.7
30–39 years	125	42.6 (0.7)	<0.05	35.3	33.6, 36.8	40.1	38.7, 42.1	48.8	45.8, 51.0
40–49 years	125	42.6 (0.7)		34.2	33.3, 37.5	41.5	40.0, 44.1	48.4	46.9, 51.3

Abbreviations: SE, standard error; $\dot{V}O_2\text{max}$, maximal oxygen uptake.

^a Age-specific estimates of the 20th, 50th, and 80th percentiles for each race/ethnicity group were presented. The 20th and 80th percentiles were chosen because these are the poor (<20th) and excellent (≥80th) fitness percentile cutpoints used in the American College of Sports Medicine's *Guidelines for Exercise Testing and Prescription* (13).

^b The *P* values refer to testing for trends of $\dot{V}O_2\text{max}$ by decades of age.

^c Total includes other race/ethnicity groups.

^d Significantly different from non-Hispanic blacks at *P* < 0.05 (with Bonferroni adjustment).

^e Significantly different from non-Hispanic whites at *P* < 0.05 (with Bonferroni adjustment).

lower educational and income levels, to have more current smokers, and to be less physically active on average. These 2 groups had similar gender and age distributions, and they had comparable mean levels of body mass index, blood pressure measurements, and total cholesterol. To further examine the potential impact of nonresponse, we adjusted the examination weights for gender, age, race/ethnicity, and any versus no reported LTPA, using the standard weighting-class method (18). For this method, variables related to nonresponse and variables related to the differential characteristics of responders and nonresponders were used to form weighting classes. It was then assumed that the data were missing at random within each adjustment cell. Nonresponse correction factors were calculated for each adjustment cell, and the adjustments were applied to the original sampling weights. In the analysis, the estimates of $\dot{V}O_2\text{max}$ using these adjusted weights led to differences no more than 0.6 mL/kg/minute or 1.1% (data not presented). This indicates that use of the original survey weights would result in very little bias. Use of the original

sampling weights is preferred in order for others to be able to replicate results without having to repeat the process to obtain a revised set of sampling weights. Therefore, we present all the estimates in this report using the original sampling weights.

RESULTS

The age-specific estimates of the mean and median $\dot{V}O_2\text{max}$, as well as the 20th and 80th percentiles for men 20–49 years of age, are presented in Table 2. The average $\dot{V}O_2\text{max}$ was 43.4, 42.7, and 43.6 mL/kg/minute for non-Hispanic white, non-Hispanic black, and Mexican-American men, respectively. There was a significant decrease in estimated $\dot{V}O_2\text{max}$ by age across all race/ethnicity groups. The difference in estimated $\dot{V}O_2\text{max}$ among race/ethnicity groups was seen only in the age group of 30–39 years and only between non-Hispanic whites and non-Hispanic blacks. No significant race/ethnicity differences were observed in other age groups.

Table 3. Mean and Selected Percentiles^a of Estimated $\dot{V}O_2\text{max}$ (mL/kg/minute) by Age and Race/Ethnicity Groups for Women 20–49 Years of Age, National Health and Nutrition Examination Surveys, 1999–2004

	No.	Mean (SE)	P Value ^b	Percentile					
				20th	95% Confidence Interval	50th	95% Confidence Interval	80th	95% Confidence Interval
Total ^c									
All ages	1,543	35.5 (0.3)		29.3	28.7, 29.9	34.3	33.6, 34.9	40.9	40.3, 41.7
20–29 years	576	36.5 (0.4)		30.6	30.0, 31.5	35.2	34.5, 35.8	41.7	40.6, 42.5
30–39 years	542	35.4 (0.4)	0.001	29.0	28.2, 30.3	34.0	33.0, 35.0	41.1	40.1, 42.6
40–49 years	425	34.4 (0.5)		28.1	27.1, 28.9	33.3	32.4, 34.4	40.0	38.7, 40.9
Non-Hispanic white									
All ages	740	35.9 (0.3) ^d		29.9	28.9, 30.6	34.7	33.8, 35.4	41.0	40.5, 42.0
20–29 years	271	36.8 (0.5)		30.9	30.2, 32.3	35.6	34.4, 36.8	41.8	40.5, 43.0
30–39 years	265	35.8 (0.4) ^d	<0.05	29.5	28.1, 30.8	34.2	33.1, 35.4	41.1	40.1, 43.1
40–49 years	204	35.1 (0.7) ^d		28.7	27.4, 29.9	34.2	32.8, 35.2	40.4	39.0, 42.0
Non-Hispanic black									
All ages	317	32.9 (0.5) ^{e,f}		27.0	25.8, 28.3	31.9	31.0, 33.2	38.0	36.6, 40.5
20–29 years	109	34.5 (0.9) ^f		28.3	26.1, 29.7	33.7	31.8, 35.3	40.7	36.8, 43.3
30–39 years	122	32.4 (0.7) ^{e,f}	<0.05	26.7	24.8, 28.4	31.4	30.2, 33.3	37.6	34.9, 40.5
40–49 years	86	31.7 (0.7) ^e		26.5	24.1, 27.4	30.7	29.3, 32.8	36.2	34.2, 38.5
Mexican American									
All ages	373	36.0 (0.5) ^d		29.4	28.6, 29.9	34.4	33.7, 35.7	42.2	40.4, 43.5
20–29 years	152	37.1 (0.6) ^d		29.8	29.3, 31.6	35.2	34.0, 36.9	43.2	40.8, 44.8
30–39 years	111	35.6 (0.8) ^d	<0.05	29.8	27.2, 31.0	34.7	32.9, 36.9	41.0	38.6, 42.9
40–49 years	110	34.2 (0.9)		27.3	26.1, 28.7	32.2	30.3, 34.3	41.1	36.7, 43.6

Abbreviations: SE, standard error; $\dot{V}O_2\text{max}$, maximal oxygen uptake.

^a Age-specific estimates of the 20th, 50th, and 80th percentiles for each race/ethnicity group were presented. The 20th and 80th percentiles were chosen because these are the poor (<20th) and excellent (\geq 80th) fitness percentile cutpoints used in the American College of Sports Medicine's *Guidelines for Exercise Testing and Prescription* (13).

^b The *P* values refer to testing for trends of $\dot{V}O_2\text{max}$ by decades of age.

^c Total includes other race/ethnicity groups.

^d Significantly different from non-Hispanic blacks at *P* < 0.05 (with Bonferroni adjustment).

^e Significantly different from non-Hispanic whites at *P* < 0.05 (with Bonferroni adjustment).

^f Significantly different from Mexican Americans at *P* < 0.05 (with Bonferroni adjustment).

As expected, women (Table 3) had a lower estimated $\dot{V}O_2\text{max}$ compared with men. The mean $\dot{V}O_2\text{max}$ for women was 35.9, 32.9, and 36.0 mL/kg/minute for non-Hispanic whites, non-Hispanic blacks, and Mexican Americans, respectively. Similar to the trend seen in men, a decline was also observed in the estimated $\dot{V}O_2\text{max}$ with age for women overall and for all 3 race/ethnicity groups. Non-Hispanic black women had an overall lower mean $\dot{V}O_2\text{max}$ than did their non-Hispanic white and Mexican-American counterparts. The differences by race/ethnicity were not always statistically significant, but the patterns were consistent across all subgroups.

Distributions of estimated $\dot{V}O_2\text{max}$ are further illustrated in Figure 1 by race/ethnicity group. For men, no significant differences were observed among the 3 race/ethnicity groups. The estimated $\dot{V}O_2\text{max}$ distribution for non-Hispanic black women was consistently lower than that of the non-Hispanic white and Mexican-American women.

Figure 2 shows the comparison of the estimated $\dot{V}O_2\text{max}$ between body mass index categories by race/ethnicity. Across all race/ethnicity groups, the estimated $\dot{V}O_2\text{max}$ was significantly lower among individuals classified as obese compared with their normal weight counterparts. With the exception of Mexican-American women, persons who were overweight also had lower fitness levels than did persons with normal weight.

The estimates of mean $\dot{V}O_2\text{max}$ shown in Figure 2 for the 3 race/ethnicity groups are tabulated in Table 4 by body mass index category. For both men and women, there was no significant difference observed between race/ethnicity groups among people who were normal weight. Among women who were classified as overweight or obese, the point estimate of mean $\dot{V}O_2\text{max}$ was significantly lower for non-Hispanic blacks than that for non-Hispanic whites or Mexican Americans. This pattern was also seen in the same direction for men, although it was not statistically significant. Because the observed pattern of race/ethnicity

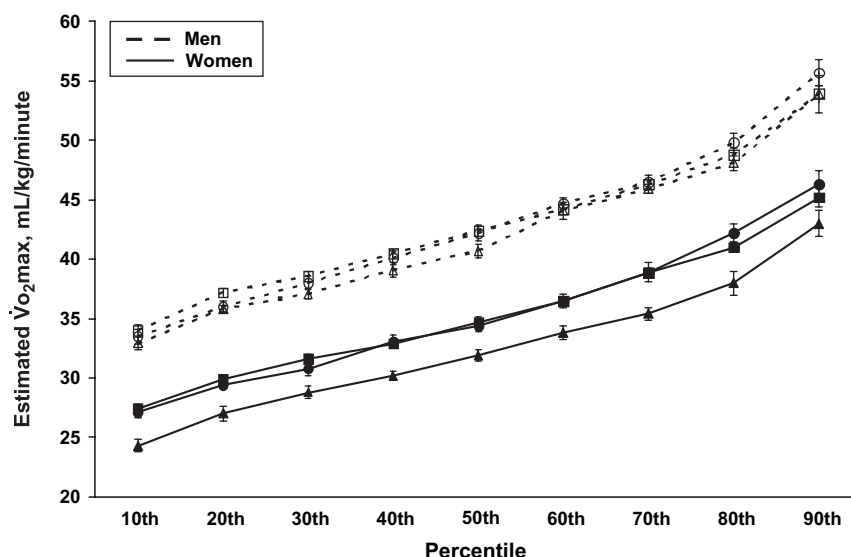


Figure 1. Distribution of estimated $\dot{V}O_{2\max}$ by race/ethnicity for men and women 20–49 years of age, National Health and Nutrition Examination Survey, 1999–2004. Dashed lines, men; solid lines, women. Open circle, Mexican-American men; open square, non-Hispanic white men; open triangle, non-Hispanic black men; filled circle, Mexican-American women; filled square, non-Hispanic white women; filled triangle, non-Hispanic black women. Error bars indicate standard errors. $\dot{V}O_{2\max}$, maximal oxygen uptake.

differences was more apparent among overweight and obese individuals than of those with normal weight, we tested the interactions between race/ethnicity groups and body mass index categories. The overall test for the interaction terms was not statistically significant.

Presented in Table 5 are the estimated mean $\dot{V}O_{2\max}$ by LTPA. For both men and women, there was a significant increase in estimated $\dot{V}O_{2\max}$ by reported LTPA levels. The 2008 *Physical Activity Guidelines for Americans* recommended at least 500–1,000 MET-minutes of activity per

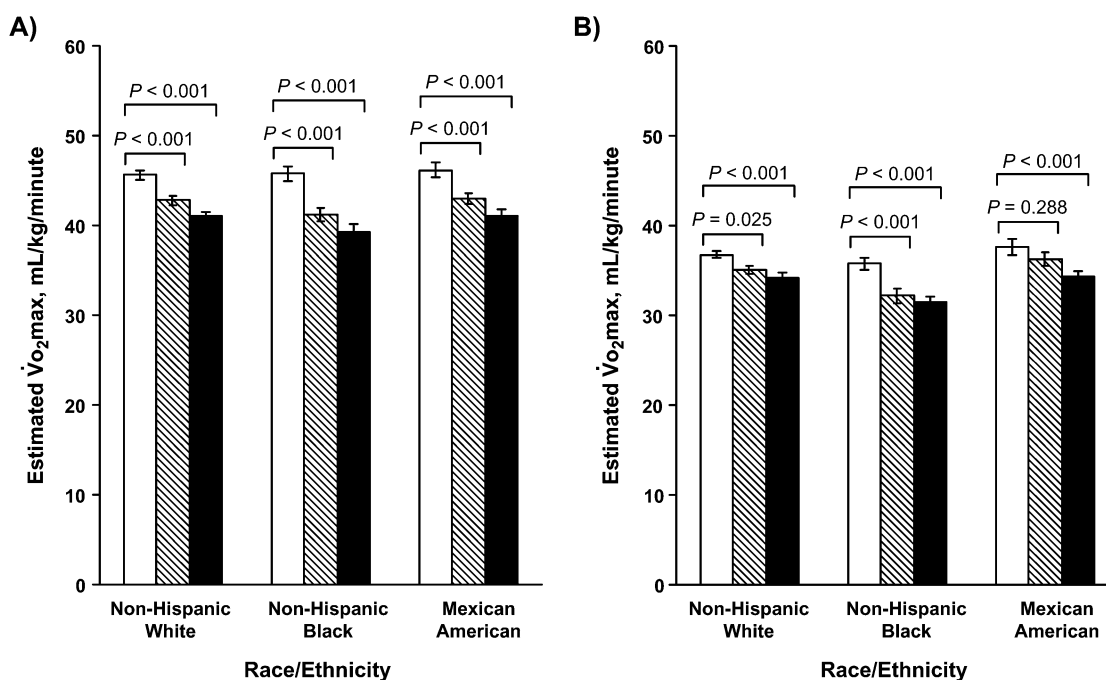


Figure 2. Estimated $\dot{V}O_{2\max}$ by race/ethnicity and body mass index categories for men (A) and women (B) 20–49 years of age, National Health and Nutrition Examination Survey, 1999–2004. White bars, normal weight; striped bars, overweight; black bars, obese. Error bars indicate standard errors. Body mass index categories defined as follows: normal weight ($18.5 < 25 \text{ kg/m}^2$); overweight ($25 < 30 \text{ kg/m}^2$); and obese ($\geq 30 \text{ kg/m}^2$). $\dot{V}O_{2\max}$, maximal oxygen uptake.

Table 4. Estimated $\dot{V}O_2\text{max}$ by Body Mass Index Categories^a and Race/Ethnicity for Men and Women 20–49 Years of Age, National Health and Nutrition Examination Surveys, 1999–2004

	Men		Women	
	No.	Mean (SE)	No.	Mean (SE)
Normal weight				
Non-Hispanic white	296	45.6 (0.5)	372	36.8 (0.4)
Non-Hispanic black	131	45.8 (0.8)	82	35.8 (0.7)
Mexican American	140	46.2 (0.8)	114	37.6 (0.9)
Overweight				
Non-Hispanic white	307	42.8 (0.5)	174	35.1 (0.4) ^b
Non-Hispanic black	112	41.2 (0.7)	85	32.2 (0.8) ^{c,d}
Mexican American	191	43.0 (0.6)	131	36.3 (0.8) ^b
Obese				
Non-Hispanic white	186	41.0 (0.5)	165	34.2 (0.6) ^b
Non-Hispanic black	78	39.3 (0.9)	146	31.5 (0.6) ^{c,d}
Mexican American	111	41.0 (0.8)	122	34.4 (0.6) ^b

Abbreviations: SE, standard error; $\dot{V}O_2\text{max}$, maximal oxygen uptake.

^a Body mass index categories defined as follows: normal weight (18.5–<25 kg/m²); overweight (25–<30 kg/m²); and obese (≥30 kg/m²).

^b Significantly different from non-Hispanic blacks at $P < 0.05$ (with Bonferroni adjustment).

^c Significantly different from non-Hispanic whites at $P < 0.05$ (with Bonferroni adjustment).

^d Significantly different from Mexican Americans at $P < 0.05$ (with Bonferroni adjustment).

week for US adults (9). Our data show that, on average, people who reported a high level of LTPA (≥1,000 MET-minutes/week) had higher $\dot{V}O_2\text{max}$ compared with those who reported no or less than 500 MET-minutes/week of LTPA. For men who reported moderate LTPA (500–<1,000 MET-minutes/week), their fitness levels, while similar to those of men with less LTPA, were significantly lower than those of men with high LTPA. For women, the difference in estimated $\dot{V}O_2\text{max}$ between high and moderate LTPA groups, however, was not statistically significant.

DISCUSSION

During the past 2 decades, increasing physical activity to improve cardiorespiratory fitness has been a major focus of health promotion and disease prevention activities in the United States. The results from the 1999–2004 NHANES describe the distribution of cardiorespiratory fitness levels for men and women aged 20–49 years without physical limitations or indications of cardiovascular disease in a national sample of the US population including 3 race/ethnicity population subgroups: non-Hispanic blacks, non-Hispanic whites, and Mexican Americans. On the basis of data from NHANES 1999–2004, the estimated mean $\dot{V}O_2\text{max}$ was 43.2 mL/kg/minute for men and 35.5 mL/kg/minute for women aged 20–49 years. Non-Hispanic black women had lower fitness levels than did non-Hispanic white and Mexican-

Table 5. Estimated $\dot{V}O_2\text{max}$ by Reported Leisure-Time Physical Activity Categories^a for Men and Women 20–49 Years of Age, National Health and Nutrition Examination Surveys, 1999–2004

Gender and Leisure-Time Physical Activity Category	No.	$\dot{V}O_2\text{max}$ (mL/kg/minute)	
		Mean (SE)	P Value ^b
Men			
No activity	531	42.1 ^c (0.5)	<0.001
Low	313	41.9 ^c (0.5)	
Moderate	206	42.1 ^c (0.5)	
High	656	45.0 (0.4)	
Women			
No activity	490	34.4 ^c (0.4)	<0.001
Low	378	34.6 ^c (0.4)	
Moderate	218	35.3 (0.7)	
High	457	37.1 (0.4)	

Abbreviations: MET, metabolic equivalent; SE, standard error; $\dot{V}O_2\text{max}$, maximal oxygen uptake.

^a Leisure-time physical activity categories defined as follows: no activity (no leisure-time physical activity reported); low (0–<500 MET-minutes/week); moderate (500–<1,000 MET-minutes/week); and high (≥1,000 MET-minutes/week).

^b The P values refer to testing for linear trends of $\dot{V}O_2\text{max}$ by leisure-time physical activity categories.

^c Significantly different from the high leisure-time physical activity group at $P < 0.05$ (with Bonferroni adjustment).

American women, whereas no significant difference was observed between race/ethnicity groups among men. The observed race/ethnicity differences were more evident among people who were overweight or obese compared with that among those with normal weight. Overall, regardless of gender or race/ethnicity, individuals who were obese had significantly lower cardiorespiratory fitness levels than did nonobese individuals. Additionally, our results also demonstrated a positive association between level of cardiorespiratory fitness and participation in leisure-time physical activity.

Our findings on the lower cardiorespiratory fitness level among non-Hispanic blacks, particularly women, compared with non-Hispanic whites and Mexican Americans, are consistent with previously reported data. The Coronary Artery Risk Development in Young Adults (CARDIA) Study examined 4,968 black adults and white adults aged 18–30 years in 1985–1986 by using symptom-limited graded treadmill exercise testing and reported that white women had higher exercise performance in both maximal and submaximal cardiorespiratory fitness measures than did black women (19). The performance was similar in white men and black men at the submaximal level but was better in whites for the symptom-limited maximal fitness measure. Farrell et al. (20) studied the fitness differences in 1,967 female school district employees among 3 race/ethnicity groups using a submaximal treadmill test. A significantly lower level of cardiorespiratory fitness was observed in black women compared with whites and Mexican Americans after adjustment for confounders.

Results from our analysis demonstrated a consistent pattern across various gender and race/ethnicity population subgroups regarding the relation between cardiorespiratory fitness level and obesity status. Compared with people who were of normal weight, those who were obese had a 10%, 14%, and 11% lower estimated $\dot{V}O_2\text{max}$ for non-Hispanic white, non-Hispanic black, and Mexican-American men, respectively. The corresponding differences in women were 7%, 12%, and 9%. Cardiorespiratory fitness has been inversely associated with mortality in normal weight, overweight, and obese individuals (7, 21–24). Results from prospective studies showed that improvements in cardiorespiratory fitness were associated with attenuated age-related weight gain (25, 26). Data from a 15-year follow-up of the Coronary Artery Risk Development in Young Adults Study cohort suggested that a low cardiorespiratory fitness level in young adults is associated with the development of cardiovascular disease risk factors, such as hypertension, diabetes, and metabolic syndrome in middle age, and is modified by obesity status (25).

When interpreting the results in this report, one must take into account the fact that the reference population does not include the subpopulation represented by individuals who were not eligible for the NHANES fitness test. To ensure the safety and validity of the test, a series of exclusion criteria were used to determine the eligibility. A total of 2,577 participants at higher risk of complications from exercise or with conditions that might affect the estimation of $\dot{V}O_2\text{max}$ did not take part in the fitness test. As a result, the population tested is younger and characterized by participants who did not have a history of or symptoms of cardiovascular diseases, severe asthma, or self-reported physical conditions that would prevent them from walking on the treadmill or who were not more than 12 weeks pregnant. The exclusion rate for the NHANES fitness test increased with age. Therefore, if the medical exclusions would lead to a healthier and more fit sample, it may be more observable among those aged 40–49 years than among the younger groups. For example, compared with the 50th percentile estimates from the Cooper Clinic Longitudinal Study with predominately white, middle and upper socioeconomic strata participants, our median estimates of $\dot{V}O_2\text{max}$ for women 20–39 years of age are 7%–8% lower (13). The differences decreased to about 4% for those aged 40–49 years. The observed divergence across age groups may be explained, at least in part, by the more heterogeneous sample in our data and by the differential exclusion rates by age.

A wide variety of submaximal exercise testing protocols have been developed and used in observational and intervention studies to examine the association of cardiorespiratory fitness and health status (1, 2). Compared with direct measurement of maximal oxygen uptake or maximal exercise testing, submaximal tests impose less of a burden on the participants in terms of time and effort. The validity of the NHANES treadmill protocol has been tested on a small sample of men and women aged 21–47 years ($n = 19$). The Pearson correlation between the estimated $\dot{V}O_2\text{max}$ from the NHANES treadmill protocol and the measured $\dot{V}O_2\text{max}$ using analysis of expired air through indirect calorimetry (13) was 0.79 (data not presented).

In addition to $\dot{V}O_2\text{max}$ being an excellent indicator of the oxygen transport and utilization capacity of the cardiorespiratory system and skeletal muscles, it is also a strong independent predictor of future cardiovascular diseases, type 2 diabetes, and all-cause mortality (2–7, 27–29). For example, a 1-MET increase in $\dot{V}O_2\text{max}$ (3.5 mL/kg/minute) has been associated with a 12% and 17% greater survival for men (30) and women (31), respectively. From this perspective, our results on an average of 2.5–3.1 mL/kg/minute difference in $\dot{V}O_2\text{max}$ between high LTPA and no or low LTPA groups suggest a noteworthy health benefit at a population level. The relative risk of all-cause mortality associated with a low level of cardiorespiratory fitness has been ranked comparable with that observed for cigarette smoking (5). Studies have demonstrated that improvement in the cardiorespiratory fitness level is associated with reduction in mortality rates (32) and can be achieved by participating in regular physical activity (33, 34).

In January 2005, revised *Dietary Guidelines for Americans* were released with an emphasis on the importance of regular physical activity (35). In October 2008, the federal government issued its first-ever *Physical Activity Guidelines for Americans* to provide science-based guidance on the types and amounts of physical activity for Americans aged 6 years or older (9). The target set by the Physical Activity Guidelines Advisory Committee for adults to achieve substantial health benefits from aerobic activity is 500–1,000 MET-minutes/week, which is the moderate range for LTPA presented in Table 5. Although the estimated $\dot{V}O_2\text{max}$ of men and women with LTPA meeting the target is not significantly higher than sedentary individuals, we did observe a significant trend for higher fitness across LTPA categories. Self-reported LTPA leads to substantial misclassification, and the questionnaire may not be sensitive enough in identifying individuals meeting current Guidelines. This underscores the importance of having objective data on fitness in surveillance systems and in making public health and clinical decisions.

To the authors' knowledge, these data are the only nationally representative estimates of mean and percentiles of fitness level and will provide an important source for comparison in future studies from the United States and other countries. This report provides a key reference that can be used to track future population assessments and to evaluate the impact of programs. Differences reported here in cardiorespiratory fitness among population subgroups and by obesity status and participation in leisure-time physical activity can be used to develop health policies, programs, and services targeted to the least active and fit in the US population.

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