

# Validity of Cardiorespiratory Fitness Criterion-Referenced Standards for Adolescents

FELIPE LOBELO<sup>1</sup>, RUSSELL R. PATE<sup>1</sup>, MARSHA DOWDA<sup>1</sup>, ANGELA D. LIESE<sup>2</sup>, and JONATAN R. RUIZ<sup>3,4</sup>

<sup>1</sup>Department of Exercise Science, Arnold School of Public Health, University of South Carolina, Columbia, SC; <sup>2</sup>Department of Epidemiology and Biostatistics and Center for Research on Nutrition and Health Disparities, Arnold School of Public Health, University of South Carolina, Columbia, SC; <sup>3</sup>Unit for Preventive Nutrition, Department of Biosciences and Nutrition at NOVUM, Karolinska Institutet, Huddinge, SWEDEN; and <sup>4</sup>Department of Physiology, School of Medicine, University of Granada, Granada, SPAIN

## ABSTRACT

LOBELO, F., R. R. PATE, M. DOWDA, A. D. LIESE, and J. R. RUIZ. Validity of Cardiorespiratory Fitness Criterion-Referenced Standards for Adolescents. *Med. Sci. Sports Exerc.*, Vol. 41, No. 6, pp. 1222–1229, 2009. **Purpose:** The clinical utility of cardiorespiratory fitness (CRF) criterion-referenced standards (FITNESSGRAM) has not been tested in adolescents. We aimed to determine the ability of the FITNESSGRAM standards to discriminate between low and high cardiovascular disease (CVD) risk in a population-based sample of US adolescents. **Methods:** Participants included 1247 adolescents (45.7% females) aged 12–19 yr. A submaximal walking treadmill test was used to estimate peak oxygen consumption as a measure of CRF. Participants were dichotomized based on meeting or failing the sex- and age-specific FITNESSGRAM standards. CVD risk factors included systolic blood pressure, sum of triceps and subscapular skinfolds, homeostatic model assessment (HOMA) of insulin resistance, triglycerides, and total cholesterol/high-density lipoprotein ratio. A sex- and age-specific CVD risk score was computed as the mean of these five standardized risk factors. A risk score >1 SD was considered to indicate a high CVD risk. **Results:** One third of the adolescents fail to meet the FITNESSGRAM standards. Body fat and CVD risk score were significantly lower in adolescents meeting versus failing the FITNESSGRAM standards (all  $P < 0.003$ ). Receiver operating characteristics curve analyses revealed that the CRF thresholds that best discriminated between low and high CVD risk were very similar to those established by FITNESSGRAM: 44.1 and 40.3 mL·kg<sup>-1</sup>·min<sup>-1</sup> among 12- to 15- and 16- to 19-yr-old boys and 36.0 and 35.5 mL·kg<sup>-1</sup>·min<sup>-1</sup> among 12- to 15- and 16- to 19-yr-old girls, respectively. **Conclusions:** The CRF criterion-referenced standards established by FITNESSGRAM discriminate adolescents with a more favorable cardiovascular profile from those with a less favorable profile. Identification of children who fail to meet these standards can help detect the target population for pediatric CVD prevention strategies. **Key Words:** FITNESSGRAM, PHYSICAL FITNESS, CARDIOVASCULAR DISEASE RISK FACTORS, YOUTH, ROC CURVE

There is increasing evidence that cardiorespiratory fitness (CRF) provides strong and independent prognostic information about the overall risk of morbidity and mortality in both healthy adults and in those with cardiovascular disease (CVD) (25). These findings have been replicated in clinical populations with diabetes mellitus, hypertension, metabolic syndrome, and several types of cancer (25).

Among children and adolescents, CVD risk status has been positively associated with obesity and inversely

associated with higher levels of CRF, even after accounting for the effect of body fat (32). Therefore, although CVD risk factors are lower in youth than in adults, the association between high CRF and low CVD risk is evident in the first decades of life.

A health-related CRF criterion value for adolescents can be useful to identify the target population for primary CVD prevention as well as for health promotion policies. In the 1990s, FITNESSGRAM established sex- and age-specific CRF cutoff values for adolescents known as Healthy Fitness Zones (13,43). The Healthy Fitness Zones were designed to represent the lowest levels of CRF (expressed as maximum oxygen consumption relative to body weight, mL·kg<sup>-1</sup>·min<sup>-1</sup>) linked to adequate functional and/or health-related outcomes in adolescents. These criterion-referenced standards were obtained by regressing, to a pediatric population, data linking CRF with all-cause and CVD mortality in adults. However, the clinical value of these CRF standards has not been tested in relation to objective measures of overall CVD risk in current generations of adolescents.

Address for correspondence: Russell R. Pate, Ph.D., Public Health Research Center, 921 Assembly St, Columbia, SC 29208; E-mail: rpate@mailbox.sc.edu.  
Submitted for publication June 2008.

Accepted for publication November 2008.

0195-9131/09/4106-1222/0

MEDICINE & SCIENCE IN SPORTS & EXERCISE®

Copyright © 2009 by the American College of Sports Medicine

DOI: 10.1249/MSS.0b013e318195d491

The objective of the present study was to examine the clinical value of the FITNESSGRAM criterion-referenced standards for CRF in adolescents. To address this objective, we compared the levels of individual and clustered CVD risk scores across CRF FITNESSGRAM categories in a population-based sample of US adolescents. To further study the construct validity of the CRF cutoffs suggested by FITNESSGRAM, we calculated, by receiver operating characteristic (ROC) analyses, the CRF threshold that best discriminates between low and high CVD risk in this population.

## METHODS

**Survey design.** This report is based on data from the 1999–2002 rounds of the National Health and Nutrition Examination Survey (NHANES), a nationally representative sample of the noninstitutionalized civilian US population (8,9). Adolescents aged 12 to 19 yr were oversampled, which allowed for more precise estimates for this group. The NHANES protocol was approved by the National Center for Health Statistics Institutional Review Board and consisted of a household interview followed by an examination at a mobile examination center. A parent or guardian of those younger than 18 yr provided written informed consent for their child's participation, and those aged 18 yr and older provided written informed consent. Participants younger than 18 yr provided written assent at the time of the household interview and the mobile examination center examination.

**Participants.** A total of 4902 adolescents aged 12 to 19 yr were interviewed at home during 1999–2002, and of these, 4732 (97%) were examined at the mobile examination center. In this report, only adolescents with complete data on CRF and CVD risk factors, including systolic blood pressure (SBP), fasting glucose, insulin, high-density lipoprotein cholesterol (HDLc), triglycerides (TG), total cholesterol (TC), and subscapular and triceps skinfolds (SKF), were included ( $n = 1247$ ). This analytic sample is comparable in demographic variables with the overall sample that was examined in the mobile examination center (35). However, in the present study sample, body mass index was 6% lower ( $22.2$  vs  $23.6$   $\text{kg}\cdot\text{m}^{-2}$ ;  $P < 0.001$ ) compared with the overall sample, and CRF was 1% higher ( $42.8$  vs  $42.2$   $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ;  $P = 0.001$ ).

**Physical examination.** Body measurements were taken by certified health technicians using the Centers for Disease Control and Prevention standardized methods and equipment. Physical examinations and laboratory measurements were performed at the mobile examination center. Skinfold thicknesses (triceps and subscapular) were measured on the right side of the body to the nearest 0.1 mm using Holtain calipers. The sum of both skinfolds was used as an indicator of total body fat. Blood pressure was measured by certified physicians trained according to the American Heart Association protocols. Three consecutive measurements were taken on the same arm after a 5-min rest (the first measurement was excluded

from the reported average) with participants in the seated position using a mercury sphygmomanometer with the appropriate cuff for the subject's age and size. If one of the measurements was interrupted or if one or more of the readings were not available, a fourth measurement was attempted.

**Blood samples.** Fasting blood samples were taken and processed locally then stored and shipped to central laboratories for analysis. Serum concentrations of TC, HDLc, TG, glucose, and insulin were measured by standardized procedures (7). The ratio of TC to HDLc (TC/HDLc) was calculated as an atherogenic index (1). The homeostasis model assessment (HOMA) was used as a surrogate measure of insulin resistance (28) and was calculated as fasting insulin ( $\text{mU}\cdot\text{L}^{-1}$ )  $\times$  fasting glucose ( $\text{mmol}\cdot\text{L}^{-1}$ ) / 22.5.

**Clustering of CVD risk factors.** The clustering of CVD risk factors was assessed by a CVD risk score, which was computed from the following variables: SBP, total body fat, HOMA, TG, and TC/HDLc. Each of these variables was standardized by subtracting the mean value for each age and sex group from the individual's value and then dividing by the value of the standard distribution. The CVD risk score was calculated as the average of the five standardized variables, separately for each sex and age. The CVD risk score is a continuous variable with a mean of zero by definition, with lower scores indicating a more favorable cardiovascular profile. Similar approaches to derive a composite CVD risk score measure in pediatric populations have been previously reported (2,39,41).

Previous investigations have shown that the prevalence of CVD risk factor clustering phenotypes such as the metabolic syndrome ranges from  $\approx 5\%$  in the general population to 30% in overweight pediatric populations (10,11,45). We used this information to inform the selection of a 1 SD cutoff point to define elevated CVD risk, which approximates a prevalence of 16%. Therefore, adolescents with a CVD risk score  $>1$  SD were defined as having a high risk.

**Cardiorespiratory fitness.** A submaximal treadmill exercise protocol was used to estimate peak oxygen consumption ( $\dot{V}\text{O}_{2\text{peak}}$ ), a measure of CRF. The test was designed to elicit an HR of approximately 80% of age-predicted maximum ( $220 - \text{age}$ ) by the end of the second exercise stage. The test was performed on a Quinton Med-Track ST65 Treadmill (Quinton, Deerfield, WI) and consisted of a 2-min warm-up, followed by two 3-min work stages and a 2-min cool-down period. Blood pressure and HR were measured at the end of each of the stages using a Colin STBP-780 Automatic Blood Pressure Monitor (Colin Medical Instruments Corp, San Antonio, TX). The  $\dot{V}\text{O}_{2\text{peak}}$  was estimated by extrapolation to an expected age-specific maximal HR using the measured HR responses to the exercise stages. All tests were supervised by trained technicians who were monitored twice a year and participated in an annual retraining session to ensure quality control. Details of the protocols and the CRF calculation formulas as well as procedures for data cleaning and quality control are published elsewhere (8,9,35).

Adolescents were classified into two levels (meeting/not meeting the CRF standards) based on the FITNESSGRAM standards for Healthy Fitness Zone, which correspond to  $\geq 42$  mL·kg<sup>-1</sup>·min<sup>-1</sup> in boys and to  $\geq 37.0$  mL·kg<sup>-1</sup>·min<sup>-1</sup> among 12-yr-old girls and to  $\geq 36.0$  mL·kg<sup>-1</sup>·min<sup>-1</sup> in 13-yr-old girls and to  $\geq 35.0$  mL·kg<sup>-1</sup>·min<sup>-1</sup> in  $\geq 14$ -yr-old girls (13,43).

**Statistical analyses.** Data are presented as means (SD) unless otherwise stated. All variables were checked for normality using both graphical (Q-Q normality plot, histogram, frequency distribution) and statistical (skewness and kurtosis values  $>1$  or less than  $-1$ ) methods and transformations were applied when necessary. HOMA and TG were left skewed and thus logarithmically transformed. Sex differences were assessed by one-way ANOVA. Mean differences for the individual CVD risk factors and the CVD risk score by FITNESSGRAM CRF categories were analyzed by one-way ANOVA. Binary logistic regression was used to further study the relationship between CVD risk score and these CRF categories. All the analyses were stratified by sex and age groups (12–15 and 16–19 yr). Final sample sizes corresponded to 308, 369, 315, and 255 for younger and older boys and girls, respectively.

Receiver operating characteristics (ROC) curves were used to calculate the CRF threshold that best discriminates between low and high CVD risk score (47). An ROC curve is a plot of all the sensitivity/specificity pairs resulting from varying the decision threshold. Sensitivity (or true-positive rate) is the proportion of the sample correctly identified as having a high CVD risk. Specificity is the proportion of subjects correctly identified as having a low CVD risk. Sensitivity is plotted on the y-axis, whereas the x-axis shows  $1 - \text{specificity}$  (false-positive rate). False-positive rate is the proportion of subjects having a low CVD risk that have been incorrectly identified as having a high CVD risk. The ideal test that correctly classifies all subjects has a

true-positive rate of 1 and a false-positive rate of 0. Therefore, the optimal combination of true-positive rate and false-positive rate is the point closest to the ideal test (*upper left corner of the graph*). To identify the best threshold, the distance between the perfect test and each sensitivity and  $1 - \text{specificity}$  pair was calculated, and then the pair closest to 1 was chosen. The area under the ROC curve (AUC) and its 95% confidence intervals (CI) were calculated for each sex and age group. The AUC represents the ability of the test to correctly classify adolescents having low versus high CVD risk. AUC values range between 1 (ideal test) and 0.5 (worthless test). Analyses were conducted using SAS v. 9.0 and SUDAAN version 9.0.1 (37) to account for the complex sampling design and to apply sampling weights in the analyses. The level of significance was set at  $\alpha = 0.05$ .

## RESULTS

The descriptive characteristics of the study sample are shown in Table 1. The prevalence of adolescents who did not meet the FITNESSGRAM standards was 31% and 27% for younger (12–15 yr) and older (16–18 yr) males, respectively, and 30% for younger and 33% for older females. Males had lower body fat and HDLc levels than females, and females had lower levels of SBP, glucose, and CRF than males. Table 2 shows the standardized means for the individual CVD risk factors by age group, sex, and CRF categories. The standardized mean of sum of SKF was significantly lower in male and female adolescents who met the CRF standards compared with those who did not meet the standards. The standardized mean of TG was significantly lower in males who met versus those who did not meet the CRF standards, whereas no difference between CRF categories was observed in females. Among both males and females aged 16–19 yr, the standardized mean of HOMA

TABLE 1. Characteristics of participants with CRF and CVD risk data aged 12 to 19 yr: NHANES 1999–2002.

Parameters	12–15 yr		16–19 yr	
	Males (n = 308)	Females (n = 315)	Males (n = 369)	Females (n = 255)
Age (yr)	13.6 (1.1)	13.5 (1.1)	17.4 (1.1)	17.3 (1.1)
Height (cm)	166.0 (10.7)	159.5 (6.8)*	176.7 (7.7)	163.6 (6.9)*
Weight (kg)	58.8 (17.3)	54.1 (13.6)*	73.5 (15.2)	60.6 (12.2)*
Body mass index (kg·m <sup>-2</sup> )	21.1 (4.8)	21.1 (4.5)	23.5 (4.5)	22.6 (4.2)
Sum of two skinfolds (mm)	22.0 (12.3)	29.7 (13.7)*	23.8 (11.4)	34.7 (13.1)*
Systolic BP (mm Hg)	107.8 (10.5)	104.6 (7.6)*	114.8 (9.7)	106.6 (9)*
Glucose (mg·dL <sup>-1</sup> )	94.3 (9.2)	89.4 (6.3)*	92.5 (7.6)	89.1 (18.3)*
Insulin (uU·mL <sup>-1</sup> )	11.5 (7.1)	12.4 (7.4)	11.01 (7.9)	11.7 (5.8)
HOMA	2.7 (0.9)	2.8 (1.7)	2.5 (1.1)	2.6 (1.4)
TC (mg·dL <sup>-1</sup> )	156.3 (27.7)	158.4 (27.8)	156.9 (29.6)	163 (27.9)
HDLc (mg·dL <sup>-1</sup> )	46.7 (10.6)	50.3 (10.8)*	46.3 (11.6)	52.1 (11.6)*
TC/HDLc	3.5 (0.9)	3.3 (0.8)	3.6 (1.1)	3.3 (0.8)*
TG (mg·dL <sup>-1</sup> )	97.6 (107.6)	86.3 (45.0)	92 (29.6)	87.4 (41.2)
CVD risk score <sup>a</sup>	0 (3.4)	0 (3.2)	0 (3.5)	0 (3)
CRF (mL·kg <sup>-1</sup> ·min <sup>-1</sup> )	47 (8.6)	39.7 (7.5)*	48.1 (9.5)	38.9 (8.6)*
% fail to meet CRF standards <sup>b</sup>	31	30	27	33

Values are presented as mean (SD).

\*  $P < 0.05$  for sex differences.

<sup>a</sup> Obtained by averaging individual risk factor (sum of two skinfolds, HOMA, TC/HDLc, SBP, and TG) standardized scores.

<sup>b</sup> Defined using FITNESSGRAM cutoffs values (13,43).

BP, blood pressure; CRF, cardiorespiratory fitness; CVD, cardiovascular disease; HDLc, high-density lipoprotein cholesterol; HOMA, homeostasis model assessment.

TABLE 2. Mean z-scores (SD) for individual CVD risk factors by categories of CRF, <sup>a</sup> age, and sex: NHANES 1999–2002.

	SBP		Skinfold Thickness		Log HOMA		Log TG		TC/HDLc	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
12–15 yr										
Meets CRF standards (n = 415)	-0.03 (0.07)	0 (0.07)	-0.18 (0.05)	-0.10 (0.07)	-0.12 (0.07)	-0.03 (0.08)	-0.15 (0.06)	0.01 (0.08)	-0.14 (0.04)	-0.05 (0.06)
Fails to meet CRF standards (n = 208)	0.06 (0.10)	0 (0.08)	0.39 (0.11)	0.23 (0.09)	0.27 (0.13)	0.07 (0.08)	0.32 (0.11)	-0.02 (0.08)	0.30 (0.14)	0.12 (0.11)
<i>P</i> <sup>b</sup>	0.5	0.9	<0.001	<0.001	0.08	0.35	<0.001	0.8	0.06	0.10
16–19 yr										
Meets CRF standards (n = 422)	-0.05 (0.07)	-0.05 (0.08)	-0.14 (0.05)	-0.21 (0.07)	-0.13 (0.06)	-0.15 (0.07)	-0.08 (0.06)	-0.05 (0.09)	-0.03 (0.07)	-0.08 (0.06)
Fails to meet CRF standards (n = 202)	0.13 (0.08)	0.10 (0.09)	0.37 (0.11)	0.42 (0.12)	0.36 (0.12)	0.30 (0.10)	0.20 (0.11)	0.10 (0.12)	0.07 (0.12)	0.16 (0.10)
<i>P</i> <sup>b</sup>	0.10	0.21	<0.001	<0.001	0.013	0.004	0.05	0.36	0.46	0.03

<sup>a</sup> Defined using FITNESSGRAM cutoffs values (13,43).

<sup>b</sup> *P* values for differences between CRF categories.

CRF, cardiorespiratory fitness; HDLc, high-density lipoprotein cholesterol; HOMA, homeostasis model assessment.

was significantly lower in those who met versus those who did not meet the CRF standards.

The CVD risk score was significantly higher among males and females who did not meet versus those who did meet the CRF standards (Fig. 1). Logistic regression analysis showed that males who met the CRF standards ( $\geq 42.0 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) had a significantly increased odds ratio (OR) of having a low CVD risk when compared with males with CRF levels below this value (12–15 yr: OR = 5.17, 95% CI = 2.44–10.95; 16–19 yr: OR = 3.78, 95% CI = 2.06–6.92; all *P* < 0.001). Females aged 12–15 yr who met the CRF standard (12 yr old:  $\geq 37.0 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ; 13 yr old:  $\geq 36.0 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ; 14 yr old:  $\geq 35.0 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) did not have a statistically significant higher OR of having a low CVD risk than those with CRF levels below these values (OR = 1.56, 95% CI = 0.72–3.39; *P* = 0.254). Females aged 16–19 yr who met the CRF standard ( $\geq 35.0 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) did not have a statistically significant higher OR of having a low CVD risk than those with CRF levels below these values (OR = 2.00, 95% CI = 0.76–5.23; *P* = 0.158).

ROC analysis showed a significant discriminating accuracy of CRF for identifying low versus high CVD risk score

in males but not in females (Fig. 2). In males, the optimal pair of true-positive and false-positive rates was 58% and 13% in those aged 12–15 yr and was 82% and 46% in males aged 16–19 yr. The respective CRF values at these points were 44.1 and 40.3  $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  in the younger and the older groups, respectively. In females aged 12–15 yr, the optimal pair of true-positive and false-positive rates was 64% and 44%, respectively, and 84% and 66% in females aged 16–19 yr. The respective CRF values at these points were 36.0 and 35.5  $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  in the younger and the older groups, respectively.

## DISCUSSION

The results of the present study suggest that adolescents who meet the CRF standards established by FITNESSGRAM have a significantly lower CVD risk score compared with those who do not meet the standards. The results did not change when the analyses were performed using CRF cutoffs calculated by ROC curve analyses. These findings reinforce the clinical validity of the FITNESSGRAM criterion-referenced CRF standards for adolescents in relation to their overall cardiovascular risk profile, measured by a composite score including blood pressure, total body fat, insulin resistance, TG, and the TC/HDLc ratio. From a public health point of view, these findings emphasize the importance of avoiding low CRF states in youth for purposes of early CVD prevention. Clinical screening and monitoring as well as epidemiologic surveillance of youth who fail to meet FITNESSGRAM CRF standards can help identify youth at increased risk of cardiometabolic diseases who could benefit from intervention programs.

Several studies have shown that children and adolescents with higher levels of CRF also have a more favorable cardiovascular profile compared with their unfit counterparts (32). Data from the Swedish and Estonian part of the European Youth Heart Study (EYHS) showed that children aged 9–10 yr who met the FITNESSGRAM standards were three times more likely to have a lower CVD risk score when compared with those who did not meet the standards

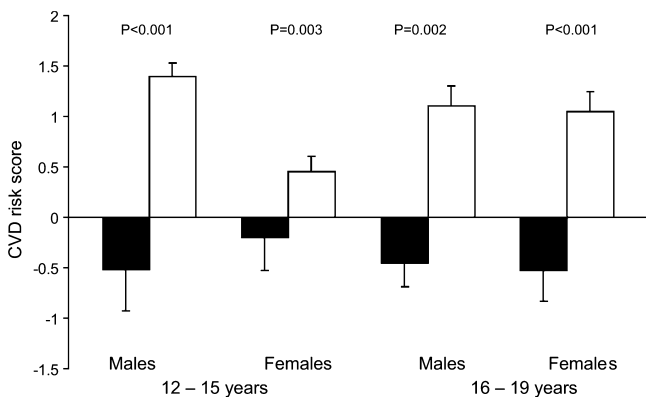


FIGURE 1—Cardiovascular disease (CVD) risk score by sex and age groups among adolescents meeting (black bars) and failing to meet (white bars) CRF standards. Data are shown as mean and SD. *P* value for differences in mean CVD risk score by CRF categories. CRF categories were defined using FITNESSGRAM cutoff values (13,43).

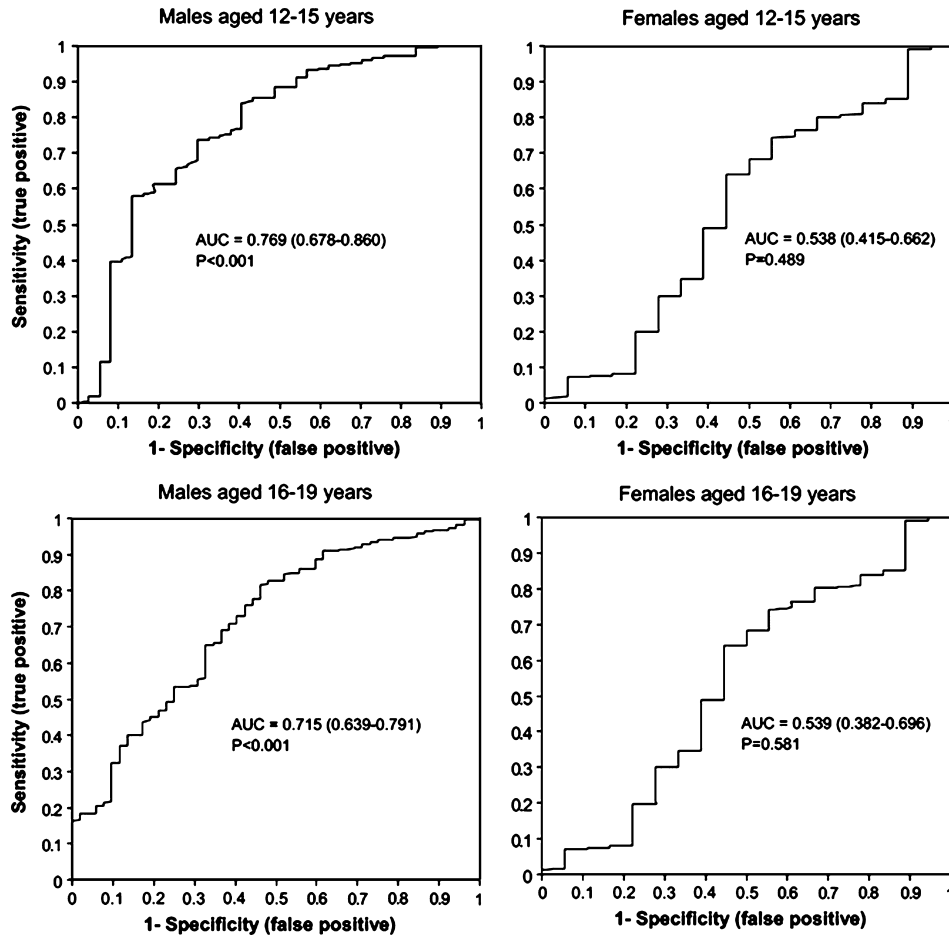


FIGURE 2—Receiver operating characteristic (ROC) curve summarizing the potential of CRF to discriminate low versus high CVD risk score in younger and older male and female adolescents. AUC, area under the ROC curve (95% CI).

(39). In the present study, males aged 12–15 yr who met the FITNESSGRAM standards were 5.17 times more likely to have a low CVD risk when compared with those who did not meet the standards. Similarly, males aged 16–19 yr who met the standards were 3.78 times more likely to have a low CVD risk when compared with those who did not meet the standards. For females, the results from the present study are less clear, similar to a study in Spanish adolescents (29). These sex differences may be because females might be protected from the deleterious consequences of having a low CRF by the role of estrogens (14). This is consistent with other studies on young people (20,23,31). Furthermore, rapid and dynamic changes in various metabolic systems, including hormonal regulation, changes in body fat content and body fat distribution, and transient changes in insulin resistance, are known to occur during growth and puberty (12). Thus, sex differences in pubertal development also may play a role in explaining these results. The results of the present study indicate that adolescents who fail to meet established criterion-referenced CRF standards are more likely to already express high CVD risk profiles and that the strength of the low CRF-high CVD risk association is greater in males than in females.

The CRF cutoffs obtained with ROC curve analyses that are associated with a low CVD risk score in the present study are very similar to those suggested by FITNESSGRAM (Table 3). Findings from the EYHS also indicate that the CRF health-related thresholds calculated by a similar mathematical method were almost identical with those proposed by

TABLE 3. Health criterion-referenced standards for CRF in children and youth.

Study/Institution	Methodology	Sex	Age (yr)	CRF Values (mL·kg <sup>-1</sup> ·min <sup>-1</sup> )
FITNESSGRAM (13,43)	Linked to adult mortality/chronic disease risk.	Males	12–19	42
		Females	12	37
			13	36
			≥14	35
European Group of Paediatric Work (3)	Expert judgment	Males	Adolescents	40
		Females	Adolescents	35
EYHS (39)	ROC curve	Males	9–10	42
		Females	9–10	37
Present study sample (NHANES 1999–2002)	ROC curve	Males	12–15	44
			16–19	40
		Females	12–15	36
			16–19	36

CRF, cardiorespiratory fitness; ROC, receiver operating characteristic.

FITNESSGRAM (39). Moreover, the European Group of Pediatric Work Physiology suggested, based on expert judgment, CRF boundaries linked to cardiovascular health, called “Health Indicator” (3), which also are quite comparable to the FITNESSGRAM standards (Table 3). It is noteworthy that the approaches used to calculate these CRF health-related thresholds were different in these previous studies, as were the age, race, nationality, environmental, and cultural and social factors of the participants studied. However, the consistency in the findings support the existence of a hypothetical CRF value linked to a more favorable CVD risk profile, as has been shown in adults.

The Cooper Institute, creator of FITNESSGRAM, estimates that 67,000 schools across the United States are currently using this program to assess CRF and other dimensions of physical fitness such as body composition, muscular strength, endurance, and flexibility (17). Several school districts including the Miami–Dade County and the New York City public schools use FITNESSGRAM district-wide. Similarly, the states of Texas, Alabama, Delaware, California, South Carolina, and West Virginia also use FITNESSGRAM to measure their students’ physical fitness annually. In addition, FITNESSGRAM standards are reported to be used by school systems and pediatric researchers in other countries (30,44). FITNESSGRAM constitutes a widely used and valid tool to identify youth failing to meet CRF standards that are linked to important health outcomes such as CVD risk. Surveillance of youth who fail to meet these CRF standards might be useful to identify the target population for CVD prevention strategies. In this regard, schools may play an important role in identifying children with low CRF via standardized field tests such as FITNESSGRAM and promoting positive fitness-enhancing behaviors. Schools can provide opportunities for children and youth to engage in at least 60 min·d<sup>-1</sup> of moderate-to-vigorous physical activity (42) and encourage them to limit to  $\leq 2$  h·d<sup>-1</sup> the time devoted to sedentary activities such as use of electronic media (26,33). The leadership of schools as a powerful setting to promote a healthy lifestyle among young populations has been recently highlighted by the American Heart Association (34). However, we acknowledge that the congested curriculum remains a barrier to implementing augmented physical education and other classroom-based strategies to promote physical activity and fitness testing in schools.

In addition, although physicians have ready access to the criterion measures of CVD (e.g., fasting blood samples, blood pressure), some of these procedures are invasive, expensive, and not suitable for CVD risk screening among large populations of children and adolescents. The information collected in schools as part of the FITNESSGRAM program is not diagnostic but could be used as part of surveillance and/or screening systems to help detect youth at high CVD risk and as such has potentially large clinical and public health implications. Unfortunately, despite the important information provided by a simple assessment of

CRF, such data rarely become available or are not used by public health and clinical practitioners for purposes of health promotion or disease prevention.

The high proportion of adolescents who failed to meet the CRF standards for a Healthy Fitness Zone in this study is of concern. Approximately one third of adolescents aged 12–19 yr in the United States fail to meet the required levels of CRF. These data are comparable with other population-based studies performed among Swedish (~40%), Estonian (~43%), Portuguese (~30%), and Spanish (~20%) children and adolescents (30,31,38). Longitudinal studies show that CRF tracks moderately from youth to adulthood (27,46) and that CRF levels during adolescence predict adult total and central body fatness (15), blood pressure (4), blood lipids (22), prevalence of metabolic syndrome (16), and large-artery stiffness (5). Collectively, these data indicate that adolescents with low levels of CRF represent an important public health concern because they already express increased levels of CVD risk factors and seem to be at a higher risk for the development of cardiometabolic morbidity and mortality (25).

CRF is influenced by several factors, including body fatness, age, sex, health status, and genetics, yet its principal modifiable determinant is habitual physical activity (6). There is a positive association between objectively measured physical activity and CRF in children and adolescents (19,40). Recent findings from observational studies also have shown an inverse association between physical activity measured by accelerometry and both individual and clustered CVD risk factors in youth (41), which highlight the pivotal role of physical activity in both increasing CRF and improving CVD profile. Intervention studies indicate that it is possible to improve CRF levels in youth by ~10% through aerobic training (36). Moreover, aerobic exercise interventions have been shown to decrease visceral fat, insulin resistance, and TG levels among overweight youth (18,24). Carefully controlled randomized clinical trials are needed to clarify the dose–response relationship between physical activity and CVD risk in youth. Interventions to improve physical activity participation among youth who fail to meet CRF standards are warranted as part of programs aimed at the early prevention of CVD risk.

In addition to physical activity, body fatness influences both CVD risk and CRF, and it might confound the association between the two. Previous studies have shown that CRF is linked to CVD risk in youth even after accounting for the role of fatness (27). In the present study, we did not attempt to assess the potential confounding effect of fatness but focused on assessing the association between CRF categories and an overall measure of CVD, which necessarily includes an index of fatness. In real life, CRF tests are measures of physical work performance, which includes movement of all the body mass, including any excess fat. However, the interpretation of a CRF variable expressed as milliliters per kilogram per minute

might be different if the focus is excess adiposity instead of performance.

Limitations of the present study include its cross-sectional nature, the limited subsample of adolescents with complete CVD and CRF data, and the use of a submaximal test to extrapolate CRF levels. However, the CRF estimation protocol applied in NHANES correlates well with direct oxygen uptake measurement (21,48), and it is adequate for large-scale epidemiological and surveillance studies. The positive predictive value of the CRF test can be affected by “false-positives,” which would be influenced by measurement error or, potentially, by lack of motivation or pacing if field tests are used. Also, it might be argued that the reliability of  $\dot{V}O_{2\max}$  estimates based on field test, as currently administered in school settings, will be lower if compared with estimates derived from laboratory-based tests that are performed under standardized and controlled conditions such as those used in the present study. A field validation is needed to evaluate if the accuracy with which high CVD risk can be predicted differs between field tests and laboratory-based submaximal tests. Such a study will have public health relevance because field tests are commonly used for assessing and monitoring  $\dot{V}O_{2\max}$  levels in the community. Finally, the results of this study are based on a sample with slightly lower (6%) body mass index and higher (1%) CRF than the overall sample of adolescents examined in NHANES, which could result in an underes-

timation of the association between low CRF and high CVD risk.

The inclusion of a relatively large number of participants, and their racial and ethnic diversity, and the use of a robust outcome variable encompassing the overall CVD risk of every individual are notable strengths of this study.

In conclusion, the results of the present study indicate that the FITNESSGRAM standards seem to discriminate adolescents with a favorable CVD profile from those with an unfavorable profile, especially among males. In the present and in a previous study, the fitness cutoffs that better discriminate low from high CVD risk in youth, calculated via ROC curve analyses, are very similar to those suggested by FITNESSGRAM, reinforcing their clinical and biological significance. Identification of children who fail to meet CRF standards can help detect youth at increased risk of cardiometabolic conditions. The FITNESSGRAM program is already widely used to measure physical fitness in school settings and can be used to guide pediatric CVD prevention strategies.

Felipe Lobelo was supported by the American College of Sports Medicine's Paffenbarger-Blair Fund for Epidemiological Research on Physical Activity. Jonatan R. Ruiz was supported by the Spanish Ministry of Education (EX-2007-1124) and the European Union in the framework of the Public Health Programme (ALPHA project, Ref: 2006120). The authors thank Gaye Groover Christmus, M.P.H., for editing the manuscript. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

## REFERENCES

- Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *JAMA*. 2001;285:2486–97.
- Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet*. 2006;368:299–304.
- Bell RD, Macek M, Rutenfranz J, Saris W. Health indicators and risk factors of cardiovascular diseases during childhood and adolescence. In: Rutenfranz J, Mocelin R, Klimt F, editors. *Children and Exercise XII*. Champaign, IL: Human Kinetics. 1986. pp. 39–42.
- Boreham C, Twisk J, Neville C, Savage M, Murray L, Gallagher A. Associations between physical fitness and activity patterns during adolescence and cardiovascular risk factors in young adulthood: the Northern Ireland Young Hearts Project. *Int J Sports Med*. 2002;23(Suppl 1):S22–6.
- Boreham CA, Ferreira I, Twisk JW, Gallagher AM, Savage MJ, Murray LJ. Cardiorespiratory fitness, physical activity, and arterial stiffness: the Northern Ireland Young Hearts Project. *Hypertension*. 2004;44:721–6.
- Bouchard C, Péruse L. Heredity, activity level, fitness, and health. In: Bouchard C, Shephard RJ, Stephens T, eds. *Physical Activity, Fitness, and Health: International Proceedings and Consensus Statement*. Champaign (IL): Human Kinetics Publishers; 1994. pp. 106–18.
- Carnethon MR, Gulati M, Greenland P. Prevalence and cardiovascular disease correlates of low cardiorespiratory fitness in adolescents and adults. *JAMA*. 2005;294:2981–8.
- Centers for Disease Control and Prevention. National Center for Health Statistics. *National Health and Nutrition Examination Survey 1999–2000 Data* [Internet]. 2004; [cited 2007 September 21]. Hyattsville (MD): US Department of Health and Human Services, Centers for Disease Control and Prevention. Available from: [http://www.cdc.gov/nchs/about/major/nhanes/nhanes99\\_00.htm](http://www.cdc.gov/nchs/about/major/nhanes/nhanes99_00.htm).
- Centers for Disease Control and Prevention. National Center for Health Statistics. *National Health and Nutrition Examination Survey 2001–2002 Data* [Internet]. 2004; [cited 2007 September 21]. Hyattsville (MD): US Department of Health and Human Services, Centers for Disease Control and Prevention. Available from: <http://www.cdc.gov/nchs/about/major/nhanes/nhanes01-02.htm>.
- Cook S, Auinger P, Li C, Ford ES. Metabolic syndrome rates in United States adolescents, from the National Health and Nutrition Examination Survey, 1999–2002. *J Pediatr*. 2008;152:165–70.
- Cook S, Weitzman M, Auinger P, Nguyen M, Dietz WH. Prevalence of a metabolic syndrome phenotype in adolescents: findings from the Third National Health and Nutrition Examination Survey, 1988–1994. *Arch Pediatr Adolesc Med*. 2003;157:821–7.
- Cruz ML, Shaibi GQ, Weigensberg MJ, Spruijt-Metz D, Ball GD, Goran MI. Pediatric obesity and insulin resistance: chronic disease risk and implications for treatment and prevention beyond body weight modification. *Annu Rev Nutr*. 2005;25:435–68.
- Cureton KJ, Warren GL. Criterion-referenced standards for youth health-related fitness tests: a tutorial. *Res Q Exerc Sport*. 1990;61:7–19.
- Donahue RP, Prineas RJ, DeCarlo Donahue R, Bean JA, Skyler JS. The female ‘insulin advantage’ in a biracial cohort: results from the Miami Community Health Study. *Int J Obes Relat Metab Disord*. 1996;20:76–82.
- Eisenmann JC, Wickel EE, Welk GJ, Blair SN. Relationship between adolescent fitness and fatness and cardiovascular disease

- risk factors in adulthood: the Aerobics Center Longitudinal Study (ACLS). *Am Heart J*. 2005;149:46–53.
16. Ferreira I, Henry RM, Twisk JW, van Mechelen W, Kemper HC, Stehouwer CD. The metabolic syndrome, cardiopulmonary fitness, and subcutaneous trunk fat as independent determinants of arterial stiffness: the Amsterdam Growth and Health Longitudinal Study. *Arch Intern Med*. 2005;165:875–82.
  17. FITNESSGRAM. FITNESSGRAM Web site [Internet]. [cited 2008 May 16]. Available from: <http://www.fitnessgram.net/home/>.
  18. Gutin B, Barbeau P, Owens S, et al. Effects of exercise intensity on cardiovascular fitness, total body composition, and visceral adiposity of obese adolescents. *Am J Clin Nutr*. 2002;75:818–26.
  19. Gutin B, Yin Z, Humphries MC, Barbeau P. Relations of moderate and vigorous physical activity to fitness and fatness in adolescents. *Am J Clin Nutr*. 2005;81:746–50.
  20. Gutin B, Yin Z, Humphries MC, Hoffman WH, Gower B, Barbeau P. Relations of fatness and fitness to fasting insulin in black and white adolescents. *J Pediatr*. 2004;145:737–43.
  21. Hartung GH, Blancq RJ, Lally DA, Krock LP. Estimation of aerobic capacity from submaximal cycle ergometry in women. *Med Sci Sports Exerc*. 1995;27(3):452–7.
  22. Hasselstrom H, Hansen SE, Froberg K, Andersen LB. Physical fitness and physical activity during adolescence as predictors of cardiovascular disease risk in young adulthood Danish. Youth and Sports Study. An eight-year follow-up study. *Int J Sports Med*. 2002;23(Suppl 1):S27–31.
  23. Imperatore G, Cheng YJ, Williams DE, Fulton J, Gregg EW. Physical activity, cardiovascular fitness, and insulin sensitivity among U.S. adolescents: the National Health and Nutrition Examination Survey, 1999–2002. *Diabetes Care*. 2006;29:1567–72.
  24. Kang HS, Gutin B, Barbeau P, et al. Physical training improves insulin resistance syndrome markers in obese adolescents. *Med Sci Sports Exerc*. 2002;34(12):1920–7.
  25. LaMonte MJ, Blair SN. Physical activity, cardiorespiratory fitness, and adiposity: contributions to disease risk. *Curr Opin Clin Nutr Metab Care*. 2006;9:540–6.
  26. Lobelo F, Pfeiffer K, Dowda M, Pate RR. Electronic media exposure and its association with activity-related outcomes in female adolescents: cross-sectional and longitudinal analyses. *J Phys Act Health*. 2009;5:137–43.
  27. Malina RM. Tracking of physical activity and physical fitness across the lifespan. *Res Q Exerc Sport*. 1996;67:S48–57.
  28. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia*. 1985;28:412–9.
  29. Mesa JL, Ruiz JR, Ortega FB, et al. Aerobic physical fitness in relation to blood lipids and fasting glycaemia in adolescents: influence of weight status. *Nutr Metab Cardiovasc Dis*. 2006;16:285–93.
  30. Mota J, Flores L, Flores L, Ribeiro JC, Santos MP. Relationship of single measures of cardiorespiratory fitness and obesity in young schoolchildren. *Am J Hum Biol*. 2006;18:335–41.
  31. Ortega FB, Ruiz JR, Castillo MJ, et al. [Low level of physical fitness in Spanish adolescents. Relevance for future cardiovascular health (AVENA study)]. *Rev Esp Cardiol*. 2005;58:898–909. Article in Spanish.
  32. Ortega FB, Ruiz JR, Castillo MJ, Sjostrom M. Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes (Lond)*. 2008;32:1–11.
  33. Ortega FB, Ruiz JR, Sjostrom M. Physical activity, overweight and central adiposity in Swedish children and adolescents: the European Youth Heart Study. *Int J Behav Nutr Phys Act*. 2007;4:61.
  34. Pate RR, Davis MG, Robinson TN, Stone EJ, McKenzie TL, Young JC. Promoting physical activity in children and youth: a leadership role for schools: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism (Physical Activity Committee) in collaboration with the Councils on Cardiovascular Disease in the Young and Cardiovascular Nursing. *Circulation*. 2006;114:1214–24.
  35. Pate RR, Wang CY, Dowda M, Farrell SW, O’Neill JR. Cardiorespiratory fitness levels among US youth 12 to 19 years of age: findings from the 1999–2002 National Health and Nutrition Examination Survey. *Arch Pediatr Adolesc Med*. 2006;160:1005–12.
  36. Pfeiffer K, Lobelo F, Ward DS, Pate RR. Endurance trainability of children and youth. In: Hebestreit H, Bar-Or O, editors. *The Young Athlete. Encyclopaedia of Sports Medicine; v. 13*. Oxford: Blackwell Publishing; 2008. pp. 84–95.
  37. Research Triangle Institute. *SUDAAN Language Manual, Release 9.0: Research Triangle Park*. Research Triangle Park (NC): Research Triangle Institute; 2004. pp. 84–95.
  38. Ruiz JR, Ortega FB, Loit HM, Veidebaum T, Sjostrom M. Body fat is associated with blood pressure in school-aged girls with low cardiorespiratory fitness: the European Youth Heart Study. *J Hypertens*. 2007;25:2027–34.
  39. Ruiz JR, Ortega FB, Rizzo NS, et al. High cardiovascular fitness is associated with low metabolic risk score in children: the European Youth Heart Study. *Pediatr Res*. 2007;61:350–5.
  40. Ruiz JR, Rizzo NS, Hurtig-Wenlöf A, Ortega FB, Wärnberg J, Sjöström M. Relations of total physical activity and intensity to fitness and fatness in children: the European Youth Heart Study. *Am J Clin Nutr*. 2006;84:299–303.
  41. Steele RM, Brage S, Corder K, Wareham NJ, Ekelund U. Physical activity, cardio-respiratory fitness and the metabolic syndrome in youth. *J Appl Physiol*. 2008;105:342–51.
  42. Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. *J Pediatr*. 2005;146:732–7.
  43. The Cooper Institute for Aerobics Research. *FITNESSGRAM Test Administration Manual*. 3rd ed. Champaign (IL): Human Kinetics; 2004. pp. 38–9.
  44. Wang GY, Pereira B, Mota J. Youth’s leisure physical activity: a case study of Chinese and Portuguese middle school students. In: Hylton K, Long J, Flintoff A, editors. *Proceedings of the Leisure Studies Association Conference. Leeds, England*. Eastbourne (UK): Antony Rowe, Ltd; 2005. pp. 93–4.
  45. Weiss R, Dziura J, Burgert TS, et al. Obesity and the metabolic syndrome in children and adolescents. *N Engl J Med*. 2004;350:2362–74.
  46. Wijndaele K, Beunen G, Duvigneaud N, et al. A continuous metabolic syndrome risk score: utility for epidemiological analyses. *Diabetes Care*. 2006;29:2329.
  47. Zweig MH, Campbell G. Receiver-operating characteristic (ROC) plots: a fundamental evaluation tool in clinical medicine. *Clin Chem*. 1993;39:561–77.
  48. Zwiren LD, Freedson PS, Ward A, Wilke S, Rippe JM. Estimation of  $\dot{V}O_{2\max}$ : a comparative analysis of five exercise tests. *Res Q Exerc Sport*. 1991;62:73–8.