Standardized Childhood Fitness Percentiles Derived from School-Based Testing

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Objective To develop a statewide school-based program of measuring and reporting cardiovascular fitness levels in children, and to create age- and sex-specific cardiovascular fitness percentile-based distribution curves.

Study design A pilot study validated cardiovascular fitness assessment with Progressive Aerobic Cardiovascular Endurance Run (PACER) testing as an accurate predictor of cardiovascular fitness measured by maximal oxygen consumption treadmill testing. Schools throughout the state were then recruited to perform PACER and body mass index (BMI) measurement and report de-identified data to a centralized database.

Results Data on 20 631 individual students with a mean age 12.1 ± 2.0 years, BMI of 21.4 ± 5.1, and a cardiovascular fitness measured with PACER of 29.7 ± 18.2 laps (estimated maximal oxygen consumption of 36.5 mL/kg/min) were submitted for analysis. Standardized fitness percentiles were calculated for age and sex.

Conclusions This study demonstrates the feasibility of performing, reporting, and recording annual school-based assessments of cardiovascular fitness to develop standardized childhood fitness percentiles on the basis of age and sex. Such data can be useful in comparing populations and assessing initiatives that aim to improve childhood fitness. Because health consequences of obesity result from both adiposity and physical inactivity, supplementation of BMI measurement with tracking of cardiovascular fitness adds a valuable tool for large-scale health assessment. *(J Pediatr 2012;161:120-4)*.

An increasing number of children are now classified as obese and fail to meet minimum recommendations for physical activity.[1] Poor physical fitness and obesity are risk factors for type 2 diabetes mellitus (T2DM) and cardiovascular disease.[2-5] Although obesity increases the risk of illness and other cardiovascular diseases,[6,7] it has been demonstrated in adults that poor cardiovascular fitness is a risk factor for illness, independent of obesity,[8] and that fitness level is a stronger predictor of mortality than obesity.[9] In both adults[10,11] and children,[12,13] it is thought that the beneficial effect of fitness training reflects the combined effects of increased lean mass and reduced fat mass. Increased fitness is associated with reduced disease in adults. In obese children, cardiovascular fitness as measured with maximal oxygen consumption (VO_2 max) and body fat are significant independent predictors of insulin sensitivity and health.[14]

From a public health standpoint, assessment of cardiovascular fitness is a vital, yet underperformed assessment. Unfortunately, the current standard for assessing cardiovascular fitness, VO_2 max, requires specialized equipment, time, and expert supervision and is therefore not practical for evaluation of large groups of children in school or community settings. A solution for fitness assessment needs to be feasible on a "large-scale," productive of valid information, and reported in a way that is useful for schools to compare their students and track effectiveness of their programs.

The Progressive Aerobic Cardiovascular Endurance Run (PACER) is a component of the Fitnessgram and consists of a multistage progressive 20-meter shuttle test. The PACER is a valid school-based test of cardiovascular fitness in pediatric populations.[15] We have previously shown in a study of 82 middle school children that the school-based PACER test closely correlates with VO_2 max measured on the treadmill ($r = 0.83$, $P < .0001$), defined as achieving at least two of these 3 criteria: (1) maximal heart rate >200 beats per minute; (2) respiratory exchange ratio (carbon dioxide consumption/oxygen consumption [VO_2]) >1.0; and (3) a plateau in VO_2. Additionally, we have shown that PACER correlates closely not only with VO_2 max, but also predictive of insulin resistance, an important marker of health.[16]

Increased physical activity in children is a key therapeutic tool for reducing obesity and improving cardiovascular fitness in the school environment.[17] What is lacking, however, is application of a valid and feasible test of cardiovascular fitness (ie, PACER) toward the development of a system by which: (1) fitness can be systematically measured, recorded, and reported throughout the state; (2) reference population ranges to allow for comparison

BMI	Body mass index
PACER	Progressive Aerobic Cardiovascular Endurance Run
T2DM	Type 2 diabetes mellitus
VO_2	Oxygen consumption
VO_2 max	Maximal oxygen consumption

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Supported by the University of Wisconsin, Wisconsin Partnership Program, which had no involvement in the design, data collection, or analysis. The authors declare no conflicts of interest.

 10.1016/j.jpeds.2012.01.036

of fitness levels to age- and sex-matched peers; and (3) goals for fitness-improving interventions and progress toward these goals can be measured.

Methods

Children (n = 82) from two local middle schools participated in the first phase of this study, to validate school-based cardiovascular fitness testing with laboratory-based cardiovascular fitness testing.[16] Each participant underwent testing at the University of Wisconsin Exercise Science Laboratory after an overnight fast. The Human Subjects Committee approved these procedures, and informed written consent was obtained before initiating the testing protocol. Testing included a physical examination and cardiovascular fitness assessment with VO_2 max. Within 14 days of this testing, the participants performed the PACER at their schools. The gold standard cardiovascular fitness assessment (VO_2 max) is determined with open-circuit spirometry using a progressive treadmill walking protocol to volitional fatigue with a Medical Graphics CPX-D treadmill (St. Paul, Minnesota). The speed of the treadmill was set initially per the subject's comfort, starting at 0% grade and increasing 2% every minute. Requirements to strictly define whether subjects reached their VO_2 max with this protocol included at least two of these 3 criteria: (1) maximal heart rate >200 beats per minute; (2) respiratory exchange ratio (carbon dioxide consumption/VO_2) >1.0; and (3) a plateau in VO_2. All the children included in the data analysis met at least two of the 3 criteria. Validation was ultimately determined with a strong correlation between the school-environment PACER test and VO_2 max (r = 0.83, $P < .0001$; 95% CI, 0.75-0.89) and PACER and fasting insulin (r = −0.61, $P < .001$; 95% CI, −0.72-−0.45). The intraclass correlation of PACER between repeated measures was 0.86, indicating a high level of test-retest reliability of the PACER.

Once the validation phase of this project was completed, the Department of Public Instruction recruited 131 schools around the state to be included in this project. The University of Wisconsin dedicated a secure website to allow uploading of local school's Fitnessgram data and also provide links to evidenced-based fitness programs and strategies for schools (http://fitness.pediatrics.wisc.edu). School staff received training, software, and support for performing Fitnessgram testing, including PACER and body mass index (BMI) determination at the schools, and for data uploading. These data from students were de-identified and securely uploaded from all participating schools in the state. After consultation with our University Human Subjects Committee, this phase of the project was determined to be "exempt from research," because there were no identifiable research subjects and the PACER testing was being performed as a routine part of the school curriculum. A total of 131 middle schools voluntarily submitted fitness data representing 20 631 unique students.

The PACER is a multistage progressive 20-meter shuttle run. Subjects run back and forth along a 20-meter course, and each minute the pace required to run the 20 meters increases. The pace is set from a pre-recorded tape or compact disk. The initial running speed is 8.5 km/hour, and the speed increases by 0.5 km/hour every minute. The test is finished when the subject fails to complete the 20-meter run in the allotted time twice.[18] The PACER is expressed as number of laps completed.

Several methods have been proposed for constructing age-dependent growth charts. Cole and Green proposed a Box-Cox transformation-based semiparametric method for normalizing the data with the Lambda-Mu-Sigma approach.[19] Wei et al recently developed a quantile regression approach for constructing age-dependent growth charts.[20] The advantage of the quantile regression method compared with the Lambda-Mu-Sigma method is that the quantile regression approach is more flexible and capable of revealing departures from underlying assumptions of parametric models.

The non-parametric quantile regression approach on the basis of B-splines was used to construct the reference growth charts for fitness and BMI. Age- and sex-specific distributions were assumed for PACER and BMI. The linear conditional quantile functions were estimated by Wei et al.[20] Estimate of the slope parameter θ was performed by using the computationally efficient simplex algorithm. The quantile regression was performed for male and female subjects separately.

Data from each school were used for constructing the PACER reference growth charts (PACER measurements from 20 631 unique subjects). VO_2 max values were predicted on the basis of PACER, age, and sex with a previously developed prediction model.[16] Earlier estimation of VO_2 max from PACER score with the Leger equation has been validated in American children and adolescents.[20] All 20 631 BMI observations were included in the analysis when constructing the BMI reference growth charts. The values of the BMI reference growth charts were compared with the age- and sex-specific percentiles provided by the Center of Disease Control (version May 30, 2000). All analyses were performed with SAS software version 9.2 (SAS Institute, Cary, North Carolina). Multivariate linear regression analysis was conducted to evaluate the association between cardiovascular fitness and BMI, after adjusting for age and sex. The partial correlation co-efficient between PACER and BMI was computed and reported with the corresponding 95% CI.

Results

PACER scores of fitness for 20 631 unique students from a statewide Wisconsin sample were used to develop reference standards shown in **Figures 1** and **2** for male and female students aged 8 to 18 years. Children had a mean age of 12.1 ± 2.0 years, BMI of 21.4 ± 5.1 kg/m^2, and a cardiovascular fitness measured with PACER of 29.7 ± 18.2 laps. The **Table** demonstrates the BMI distribution and corresponding percentiles of all students from the Wisconsin database compared with the Centers for Disease Control and Prevention BMI percentile curves published in 2000. A total of 131 schools submitted data of 424 districts in the state, thus representing approximately 31% of school districts.