Comparison of two versions of the PACER aerobic fitness test

by

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A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Exercise and Sport Science (Biological Basis of Physical Activity)

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Iowa State University

Ames, Iowa

2004

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Introduction

To combat health consequences of a sedentary lifestyle, physical education curriculums have attempted to educate students about the benefits of physical activity and teach behavioral skills that can be used into later life (1). Fitness testing is a common component of most physical education programs because it provides schools and teachers with a way to document and track important dimensions of health-related fitness. It also provides a way to offer feedback to students and parents that may help children develop more active lifestyles. While it is important to have adequate levels of fitness in each component of health related fitness, aerobic capacity (an indicator of cardiovascular fitness) is generally considered to be the most important fitness measure due to its association with coronary heart disease risk (2).

Aerobic capacity can be measured accurately under laboratory conditions using a maximal treadmill or bike-test protocol. However, due to the high cost of the equipment necessary for testing and the time required for individual assessment, this type of procedure is not practical for school-based fitness assessments. A number of field tests have been developed to allow aerobic capacity to be estimated outside of the laboratory. Field tests for aerobic capacity must be valid, reliable, easily administered, allow simultaneous assessment, require minimal equipment, and be non-invasive in nature. All of the major physical fitness assessment batteries in the United States include an assessment of aerobic capacity using a field test measure.

The Progressive Aerobic Cardiovascular Endurance Run (PACER) is the recommended test for aerobic capacity in the *FITNESSGRAM* ® assessment battery (*3*). The PACER test consists of running a 20-meter shuttle course with 1-minute paced stages at an initial running speed of 8.5 km h^{-1} with an increasing speed of 0.5 km h^{-1} per stage (4). The PACER assessment protocol has several advantages over other commonly used distance running tests such as the mile run. The protocol can be performed inside, which eliminates environmental limitations and influences on testing. The test avoids problems with pacing since the tones on the audio CD indicate the required running pace. An additional benefit of the testing protocol is that participants run together instead of having subjects clearly ahead or behind. The design characteristics of the PACER test stimulate a motivational environment for testing because the most fit youth is the last to complete the test instead of the least fit youth. (5). The PACER protocol is progressive in nature allowing much of the test to be performed at a submaximal sustainable effort. Only the final stages would require a maximal effort from the participant. These factors help to reduce stress and motivational concerns associated with fitness testing.

The validity of the PACER test has been examined by comparing scores on the test (maximum running speed, number of levels completed, or number of laps) with measured VO_2max from a treadmill-based protocol. The validity has been well supported as studies have reported correlation coefficients ranging from $r = 0.69$ and $r = 0.87$ (4, 6,7,8). The reported test-retest reliability of the PACER protocol in school age children is generally high with correlation coefficients ranging from $r = 0.82$ to $r = 0.93$ (4, 5, 8, 9).

The PACER test has proven to be an effective assessment tool for many physical education programs. However, one problem limits its overall utility - many schools have gyms or physical education classrooms that are not 20 meters in length. The test could be administered outdoors, but this makes testing contingent on weather and increases risks. The development of a shorter length PACER protocol would result in a more versatile field test because it would allow administration of the test in smaller facilities.

The variables included in the PACER's prediction equation for aerobic capacity are age and maximum running speed (4). By changing the time intervals on the audio CD the one-minute stages and running speed by stage could be maintained. This would allow the same prediction equation to be used for the 15m test as for the 20m test. However, there are several issues that could influence results using a shorter protocol. The number of laps per level has to increase with a shorter distance, thus increasing the number of turns. This would increase the amount of acceleration / deceleration for the test and could lead to premature fatigue. In addition, the increased number of laps could potentially result in premature drop out due to boredom. Before a shorter test can be promoted for use in schools it is important to address these possible confounds.

This study compares the utility of the standard 20-meter PACER test with an alternative 15-meter PACER protocol in 5^{th} and 8^{th} grade children. Specifically this study determined 1) the aerobic capacity estimates (VO_2 max) obtained from the two protocols and 2) the classification agreement between protocols for attaining the healthy fitness zone (a criterion-referenced standard). The hypotheses were that 1) there would be no difference between aerobic capacity estimates from the 15 and 20 meter protocols for both genders and both age groups and 2) classification agreement for attaining the Healthy Fitness Zone (a criterion referenced standard in the *FITNESSGRAM* test battery) would exceed 80%.

Methods

Subjects

A total of 204 students from selected physical education classes in the Ames Community School District (ACSD) were recruited to participate in the project. The sample included a total of 82 fifth grade students (49 M, 33 F) and 122 eighth grade students (75 M, 47 F). All aspects of this research were reviewed and approved by the ISU IRB before the research was begun. Informed consent was obtained from parents and assent was obtained from the children prior to testing.

Procedures

Testing was performed during normal physical education classes. Children in the ACSD are already familiar with the PACER protocol, although the purpose and procedures for the testing were explained prior to each test. A researcher demonstrated the testing procedure and identified the change of lap and change of level tones on the audio CD. Participants performed the 15m and 20m protocols approximately one week apart in a counterbalanced design by class section. Participants wore a numbered jersey to assist with recording of results by the research team. Participants completed the testing in groups of 10 or 15 students and a maximum 5:1 subject to recorder ratio was maintained. Participants were encouraged to give a maximal effort during testing to ensure an accurate estimate of aerobic capacity for both tests.

Data Processing

A total of 180 students (76, fifth grade; 104, eighth grade) completed both versions of the PACER test. Observations during the trials indicated that some students did not give equivalent effort on both versions of the test. To avoid error due to incomplete effort, students that had differences of four or more levels between the two assessments were removed from the analyses. There were a total of 9 students that had differential effort on the two tests. They consisted of three 5th grade boys and six 8th grade boys. There was no apparent pattern between the protocols with four incomplete effort trials on the 20m protocol and 5 incomplete effort trials on the 15 m protocol. Because the order of administration was counterbalanced in the study, there would be no systematic bias introduced by differences in effort between the two tests. The final sample for all subsequent analyses was the remaining 171 students (5th : 37 M, 31 F; 8th : 60 M, 43 F) that exhibited similar effort on both tests.

Another issue that could confound the test results is the determination of the participant's number of completed laps. The test protocol allows students to self-select out of the test but also specifies that students should be stopped if they fail to reach the line for two consecutive tones on the audio CD. For a sub-sample of participants, two independent observers were used to record student lap numbers to ensure that this information was recorded accurately. Correlations between the primary and secondary recorders lap counts were computed for the 15m and the 20m PACER. Primary and Secondary recorder data were available for 68 15m and 75 20m trials. Correlations were high between recorders with $r = 1.0$ and $r = 0.99$ for the 15m and 20m PACER, respectively. Primary recorder lap count values were used for all further analyses.

Analysis

Means and standard deviations from each of the assessments were calculated and reported separately for both age and gender groups as well as combined. Correlations were computed between the raw lap counts for both tests to provide an indication of overall agreement between the two protocols. Correlations were calculated for each age and gender group as well as combined.

Differences in absolute VO_2max estimates from the two protocols were analyzed using a two-way (age x gender) repeated measures analysis of variance (ANOVA). A p-value of 0.05 was used to evaluate the significance of the interaction term and the main effects. Bland-Altman plots were used to examine the agreement between the two assessments across the range of VO_2 max estimates. The Bland-Altman plots display the mean of the 15m and 20m VO_2 max estimate for an individual on the X-axis and the difference between the estimates (20m-15m) on the Y-axis. A mean difference value of zero suggests that there is no difference between protocols in VO_2 max estimates. Correlations between data points on the Bland-Altman plots are used to determine if there is any form of systematic bias across a range of fitness levels. In this analysis a significant correlation or slope may suggest that test performance between protocols may be dependent on fitness level. Classification agreement for achieving the Healthy Fitness Zone (a criterion referenced standard) on the *FITNESSGRAM* report was evaluated using chi-square analyses.

Results

Descriptive statistics for the participants are presented in Table 1. The overall difference in estimated VO_2 max between the two tests was 1.2 ml/kg/min (SD = 3.2), and this multivariate F test was significant, [$F(1,167 = 15.7, p < .001$]. The difference was slightly larger for males (1.6 $\pm$ 3.3 ml/kg/min) than females (0.6 $\pm$ 3.1 ml/kg/min) so the gender by method interaction was significant [$F(1,167)= 4.20, p = .042$]. The main effect for methods was also significant but the effect sizes for all differences were small (< 0.30) and probably not of clinical significance. The overall main effect for gender was significant ($p < 0.05$) with boys scoring higher on both the 15m PACER and 20m PACER test.

The correlations between laps, levels and VO_2 estimates from the two tests are presented in Table 2. The overall correlation of VO_2 estimates between the tests was moderate ($r = 0.76$). Correlations between VO_2 max estimates were slightly higher for males ($r = 0.79$) than for females ($r = 0.67$). Correlations were higher for the 8th grade children (M, $r = 0.85$; F, $r = 0.71$) than for 5th grade children (M, $r = 0.61$; F, $r = 0.53$).

Bland Altman plots were used to examine agreement between tests across the range of fitness levels. Separate graphs were produced for each of the four gender by grade comparisons. The plots are shown below in Figures 3 and 4. The solid line depicts the mean difference in the two tests and the dotted lines show the boundaries for the 95% confidence interval. Nearly all of the data points fell within the 95% confidence intervals. Correlations between the individual means and differences in VO2 max estimates showed a significant correlation of $r = 0.54$ for 8th grade males suggesting that for this sub-sample, less fit individuals performed better in the 15m test and more fit individuals performed better in the 20 meter test. Correlations for the 8th grade females, 5th grade males, and 5th grade females were not significant, indicating no fitness related bias between protocols in the remaining sub-samples.

Classification agreement was tested by looking at passing rates on the *FITNESSGRAM®* criterion referenced standards. Participants were classified into the Healthy Fitness Zone (HFZ) or the Needs Improvement (NI) category for both tests. The 2x2 classification table is shown in Table 3. Subjects in the NI category or the HFZ category on both tests are placed on the diagonal of the matrix, the top left or bottom right box respectively. Subjects in the NI category on one test and the HFZ category on another test are in the adjoining cells. The totals from the top left and bottom right cells represent the classification agreement between the tests. The overall classification agreement was 88% for males and 91% for females. The misclassification was evenly distributed for females, but males were more likely to pass the 20m than the 15m. Eight males passed the 20m test and failed the 15 meter test while only 4 males passed the 15m test and failed the 20m test.

Discussion

This study examined the utility of a 15m version of the well-established PACER test. The 15m PACER protocol successfully maintained the critical properties, one-minute levels and running speed by level, of the 20m PACER establish by Leger et al. (4). The number of seconds per level ranges from 60 to 66 seconds for the 20m protocol and from 58 to 65 seconds in the 15m protocol. Minor differences in actual running speed exist between the protocols due to the way that the number of laps per level are computed for the audio CD. The mean difference between running times for the first 8 levels is 0.05 ± 0.06 km h^{-1} and the overall difference for the complete 15 level comparison was 0.12 ± 0.11 km h^{-1}. The speed difference is slightly higher in the upper levels. This is not be a major concern as the majority of elementary school age children are not be able to reach the upper levels of the PACER test.

Overall, data on laps performed and VO_2 max estimates follow typical patterns with 8^{th} grade values higher than 5^{th} grade and male values higher than female. The data for laps performed and corresponding VO_2 max estimates from the 20m PACER obtained in this study is marginally lower than has been reported in previous studies examining similar populations (7, 8). However, our data were collected on all students in the general physical education classes of schools tested and would likely demonstrate lower performance than a sample of students who volunteered for a study involving a maximal test. Additionally it is possible that the lower values are reflective of secular changes in physical activity and fitness levels over time or due to the nature of the samples.

The principal finding in this study was that the 15m protocol yields similar information about aerobic fitness as the well-established 20m protocol. The overall differences in VO_2 max estimates between the 15m protocol and 20m protocol were small

(1.2 ml/kg/min). Differences varied somewhat by grade and gender (range: 0.7 ml/kg/min to 1.8 ml/kg/min), but the effects sizes of the differences were all less than 0.30.

The differences in estimates from the two versions of the PACER are comparable to differences between other field tests of fitness in children. Mahar et al., reported differences between VO_2 estimates for the 20m PACER and the Mile Run in 266 4th and 5th grade students (9). Differences of 0.9 and 1.6 ml/kg/min were reported for boys and girls, respectively. Recent work in our laboratory reported differences between VO_2 estimates for the 20m PACER and the Mile Run in 473 7th and 8th grade students (10). Differences of 1.6 and 1.8 ml/kg/min were reported for boys and girls, respectively.

The increased number of laps per level and proportionate increase in the number of turns in the 15m protocol were considered as potential limitation to the utility of the modified assessment. However, the small differences in VO_2 max estimates between protocols suggest that the modification to the protocol had little effect on the functional performance of the field test. The utility of the 15m protocol is further supported by the balanced distribution of difference scores on the Bland-Altman plots. The only plot that exhibited a tendency toward differential test performance by fitness level was for the 8th grade boys.

Boys with higher fitness levels performed better on the 20m protocol than the 15m protocol. It is possible that early withdrawal due to boredom contributed to this trend but it could also have been due to other factors such as fatigue from turns. The boys with lower fitness levels performed better on the 15m protocol than the 20m protocol. This may be the result of a psychological perception that the shorter length protocol required less work or was easier than the longer length protocol.

The impact of any potential boredom withdrawal at higher levels of the 15m PACER does not significantly impact the overall utility of the test. The decision to use the 15m

PACER protocol would be driven by the type of physical education facilities available to teachers. The majority of smaller facilities that lack adequate room to utilize the 20m PACER are located in elementary school buildings and children in these schools would not reach the higher lap counts where fatigue (from turns) or boredom could have an impact. Even though 8th grade physical education facilities would likely be capable of utilizing the 20m protocol, the inclusion of the 8th grade participants allowed the protocols to be compared across a broader range of fitness scores.

One potential limitation of this study is the lack of a criterion test. However, the validity of the PACER assessment in school age children has been well established in the literature. Leger et al., demonstrated a moderate correlation ($r = 0.71$) between predicted VO_2 max from the 20m PACER with measured VO_2 max by retro extrapolation of the O_2 recovery curve in boys and girls age 8-18 (4). Several other studies, with comparable samples to the present study, have reported significant correlations between cycle or treadmill measured VO_2 max and either maximum running speed or laps (6, 7, 8). The overall correlations in these studies ranged from $r = 0.69$ to $r = 0.87$.

In conclusion, both the 15m and 20m PACER protocols provide similar information about aerobic capacity. The differences between aerobic capacity estimates from the 15m and 20m PACER protocols found in the present study are similar to differences typically found in studies comparing other field based aerobic capacity estimates such as the 20m PACER and the Mile Run. The results of the study suggest that the 15m PACER protocol could be used in place of the 20m PACER protocol when available facilities cannot accommodate the longer testing protocol.

The design characteristics of the PACER test make it a more enjoyable assessment for children to complete. This is an important consideration in fitness testing since attitudes about physical education may influence overall attitudes to physical activity. The validation of the 15m PACER protocol addresses an important need in physical education by making this test accessible to more students. The opportunity to utilize the PACER test in place of the Mile Run may improve student effort or motivation during fitness testing and may leave students with more positive feelings associated fitness testing in physical education curriculums.

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Tables and Figures

Table 1. Descriptive statistics on laps, levels, and VO_2 max estimates by gender, grade level, and combined for the 20 and 15 meter PACER .

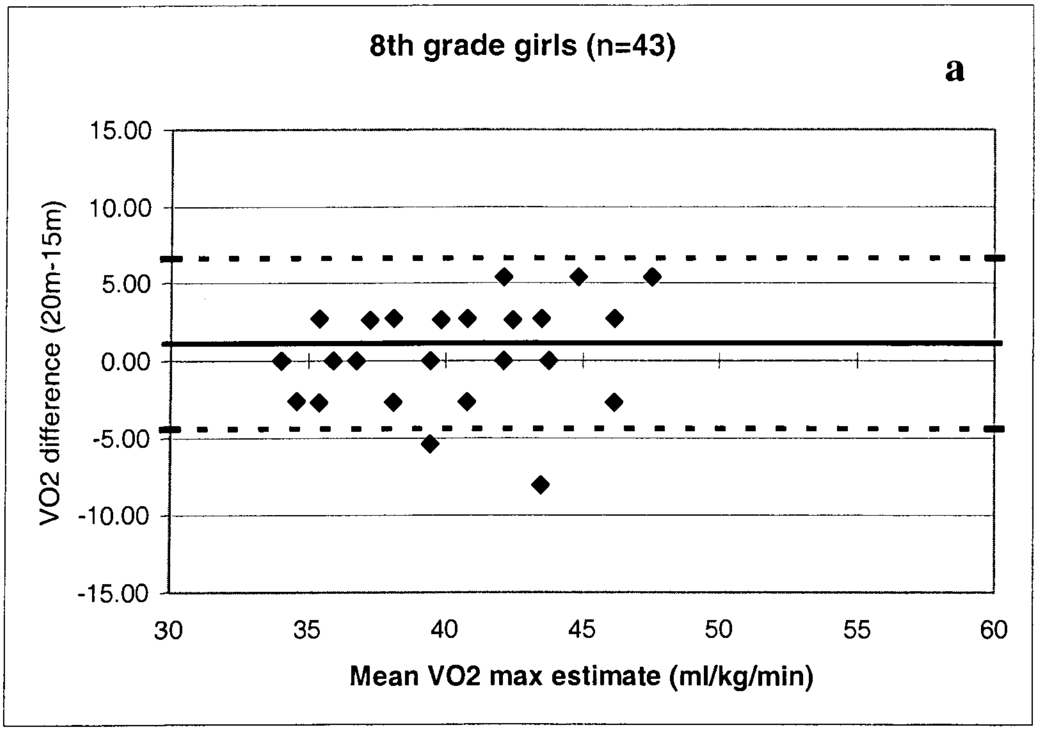
	Male			Female			All		
	(n)	Mean	S.D.	(n)	Mean	S.D.	(n)	Mean	S.D.
5th Grade									
P15 Laps	37	33.8	15.7	31	31.8	16.6	68	32.9	16.0
P20 Laps	37	31.2	12.9	31	23.6	10.8	68	27.8	12.5
P15 Levels	37	3.8	1.3	31	3.5	1.5	68	3.7	1.4
P20 Levels	37	4.4	1.5	31	3.5	1.3	68	3.9	1.5
P15 VO2 (ml/kg/min)	37	44.3	3.4	31	43.7	3.8	68	44.0	3.6
P20 VO2 (ml/kg/min)	37	45.7	4.0	31	43.6	3.3	68	44.7	3.8
8th Grade									
P15 Laps	60	55.0	21.5	43	38.2	15.0	103	48.0	20.7
P20 Laps	60	49.1	23.4	43	32.6	13.9	103	42.2	21.5
P15 Levels	60	5.5	1.7	43	4.1	1.3	103	4.9	1.7
P20 Levels	60	6.1	2.3	43	4.5	1.5	103	5.4	2.2
P15 VO2 (ml/kg/min)	60	43.6	4.3	43	40.1	3.3	103	42.2	4.3
P20 VO2 (ml/kg/min)	60	45.4	6.0	43	41.2	4.0	103	43.6	5.6
All									
P15 Laps	97	46.9	22.0	74	35.5	15.9	171	42.0	20.4
P20 Laps	97	42.3	21.8	74	28.8	13.4	171	36.5	19.8
P15 Levels	97	4.8	1.7	74	3.8	1.4	171	4.4	1.7
P20 Levels	97	5.4	2.2	74	4.1	1.5	171	4.8	2.1
P15 VO2 (ml/kg/min)	97	43.9[a]	4.0	74	41.6[a]	3.9	171	42.9[b]	4.1
P20 VO2 (ml/kg/min)	97	45.5[a]	5.0	74	42.2[a]	3.8	171	44.1[b]	5.0

P15 = 15m PACER
P20 = 20m PACER
[a] significant gender by method interaction
[b] significant difference by method

Table 2. Pearson correlations between laps, levels, and VO_2 max estimates by gender, grade level, and combined for the 20 and 15 meter PACER .

Grade	Males	Females	All
5th Grade			
Laps P20 vs P15	0.58	0.54	0.55
Level P20 vs P15	0.56	0.48	0.52
VO2 P20 vs P15	0.61	0.53	0.57
8th Grade			
Laps P20 vs P15	0.91	0.83	0.91
Level P20 vs P15	0.87	0.74	0.85
VO2 P20 vs P15	0.85	0.71	0.84
All			
Laps P20 vs P15	0.87	0.72	0.84
Level P20 vs P15	0.82	0.65	0.79
VO2 P20 vs P15	0.79	0.67	0.76

Correlations significant at the $p < 0.01$ level



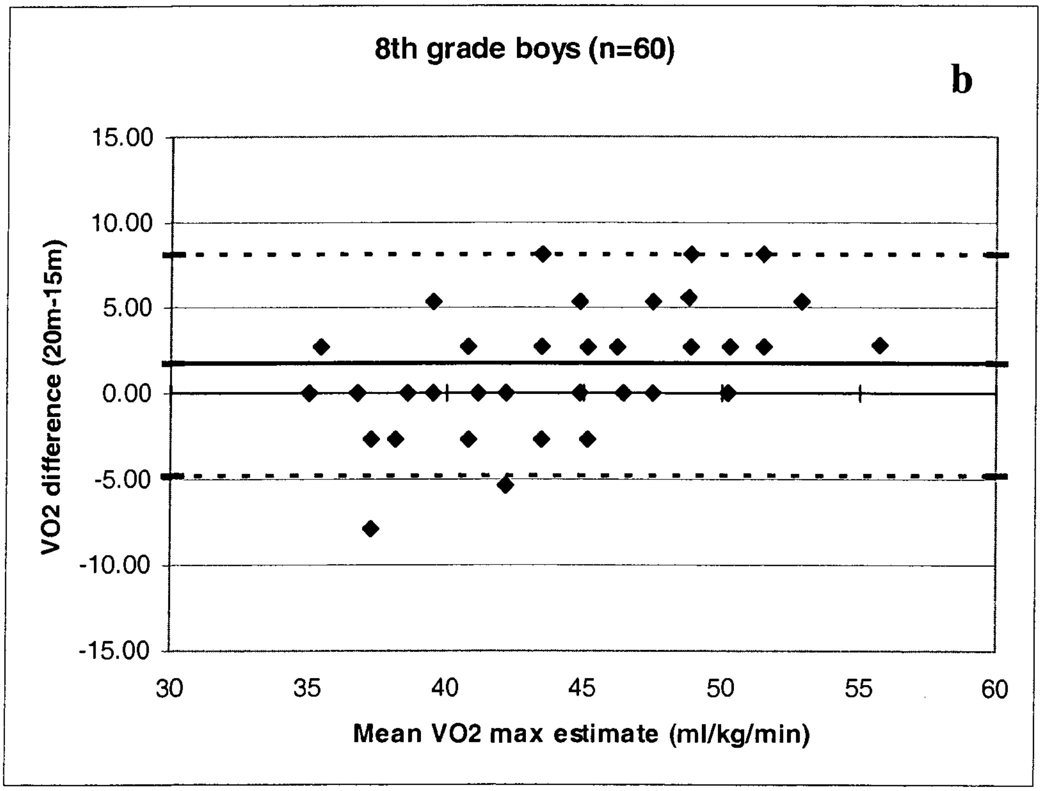


Figure 1. Bland-Altman plots for 8th grade girls (a) and boys (b).

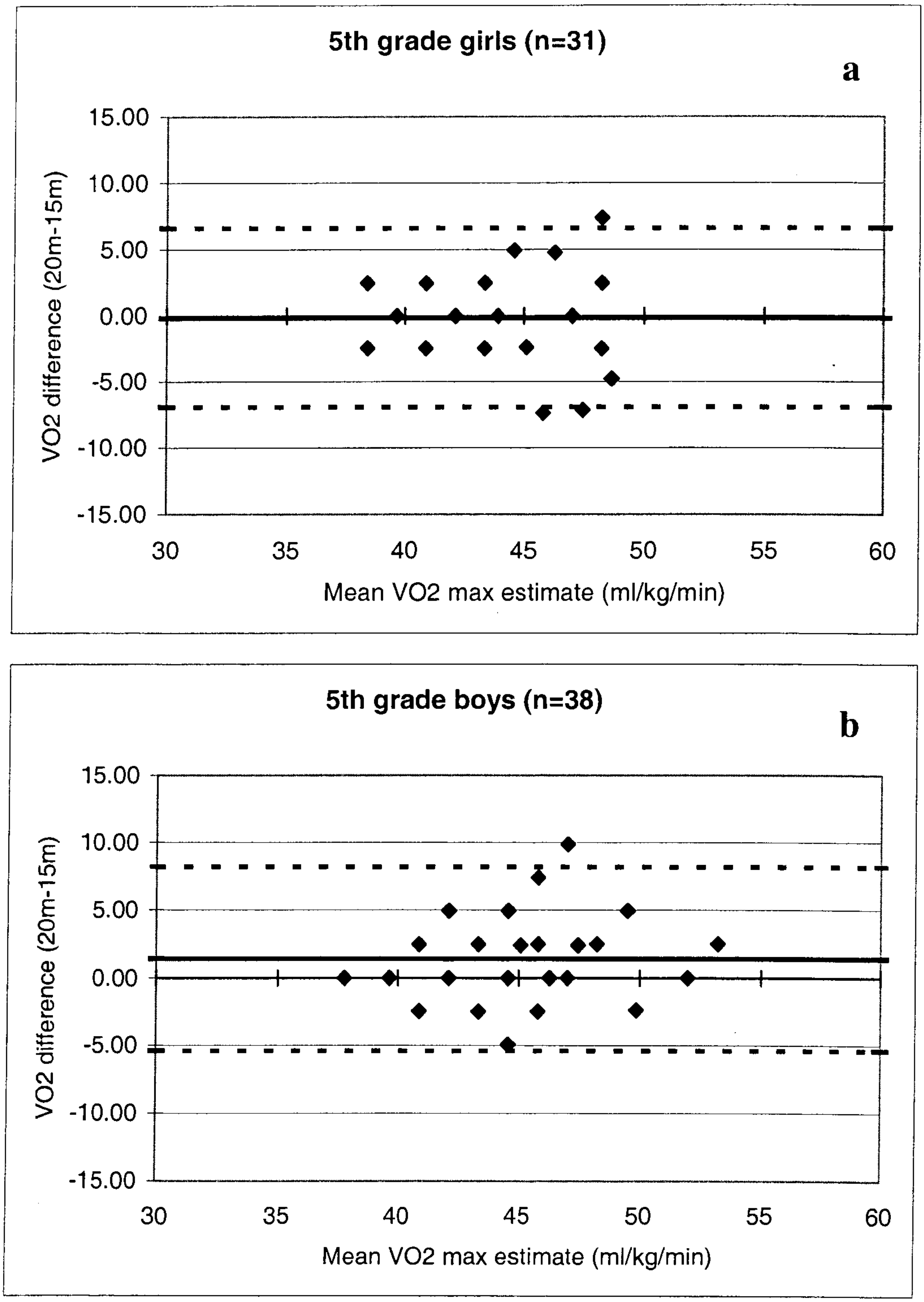


Figure 2. Bland-Altman plots for 5th grade girls (a) and boys (b).

Table 3. Classification agreement for reaching the Healthy Fitness Zone by gender, grade level, and combined for the 20 and 15 meter PACER.

5th Males

		HFZP15		
HFZP20		**NI**	**HFZ**	**Total**
NI	**% (n)**	**10.8 (4)**	2.7 (1)	13.5 (5)
HFZ	**% (n)**	5.4 (2)	**81.1 (30)**	86.5 (32)
Total	**% (n)**	16.2 (6)	83.8 (31)	100.0 (37)
		% Agreement		**91.9**

5th Females

		HFZP15		
HFZP20		**NI**	**HFZ**	**Total**
NI	**% (n)**	0.0 (0)	6.5 (2)	6:5 (2)
HFZ	**% (n)**	6.5 (2)	87.1 (27)	93.6 (29)
Total	**% (n)**	6.5 (2)	93.6 (29)	100.0 (31)
		% Agreement		**87.1**

8th Males

		HFZP15		
HFZP20		**NI**	**HFZ**	**Total**
NI	**% (n)**	**21.7 (13)**	5.0 (3)	26.7 (16)
HFZ	**% (n)**	10.0 (6)	**63.3 (38)**	73.3 (44)
Total	**% (n)**	31.7 (19)	68.3 (41)	100.0 (60)
		% Agreement		**85.0**

8th Females

		HFZP15		
HFZP20		**NI**	**HFZ**	**Total**
NI	**% (n)**	**7.0 (3)**	2.3 (1)	9.3 (4)
HFZ	**% (n)**	4.7 (2)	**86.1 (37)**	90.7 (39)
Total	**% (n)**	11.6.(5)	88.4 (38)	100.0 (43)
		% Agreement		**93.1**

All Males

		HFZP15		
HFZP20		**NI**	**HFZ**	**Total**
NI	**% (n)**	**17.5 (17)**	4.1 (4)	21.7 (21)
HFZ	**% (n)**	8.3 (8)	**70.1 (68)**	78.4 (76)
Total	**% (n)**	25.8 (25)	74.2 (72)	100.0 (97)
		% Agreement		**87.6**

All Females

		HFZP15		
HFZP20		**NI**	**HFZ**	**Total**
NI	**% (n)**	**4.1 (4)**	4.1 (4)	8.1 (6)
HFZ	**% (n)**	5.4 (4)	**86.5 (64)**	91.9 (68)
Total	**% (n)**	9.5 (7)	90.5 (67)	100.0 (74)
		% Agreement		**90.6**

Appendix A: 15m PACER dissemination

The results of the present study were presented in a draft report to the *FITNESSGRAM* Scientific Advisory Board in June of 2004. Following review the board recommended the inclusion of the 15m PACER as an alternative test for aerobic capacity in the *FITNESSGRAM* test battery. The 15m PACER test will be included in the current software revision (v. 8.0) which is expected to be released in the spring of 2005.

The demand for a 15m PACER protocol was driven by the types of physical education facilities available to teachers. Ames is no exception with several elementary school with very small gyms. We have distributed the 15m PACER CD to all of the Ames Community School District Elementary Physical Education instructors as well as a number of other P.E. instructors who have contacted *FITNESSGRAM* directly regarding a shorter length PACER protocol. The dissemination of the 15m PACER provides further support for the utility of this project.

Appendix B: PACER protocol comparison: laps, levels, time

20m PACER												
												15m PACER
Seconds / Level	Lap Total	# of Laps	**Avg. Speed**	Raw data km/hr	*Published km/hr	**Level**	km/hr	**Avg. Speed**	# of Laps	Lap Total	Seconds / Level	
63	7	7	**8.00**	8.00	8.5	**1**	7.97	**7.97**	9	9	61	
64	15	8	**8.50**	9.00	9	**2**	9.00	**8.48**	10	19	60	
61	23	8	**8.81**	9.44	9.5	**3**	9.43	**8.80**	11	30	63	
65	32	9	**9.10**	9.97	10	**4**	9.97	**9.09**	12	42	65	
61	41	9	**9.41**	10.62	10.5	**5**	10.45	**9.36**	12	54	62	
65	51	10	**9.69**	11.08	11	**6**	10.97	**9.63**	13	67	64	
63	61	10	**9.93**	11.43	11.5	**7**	11.51	**9.90**	13	80	61	
66	72	11	**10.19**	12.00	12	**8**	12.00	**10.16**	14	94	63	
64	83	11	**10.44**	12.38	12.5	**9**	12.60	**10.43**	14	108	60	
60	94	11	**10.71**	13.20	13	**10**	12.86	**10.68**	15	123	63	
65	106	12	**10.95**	13.29	13.5	**11**	13.50	**10.93**	15	138	60	
61	118	12	**11.21**	14.16	14	**12**	13.94	**11.18**	16	154	62	
64	131	13	**11.48**	14.63	14.5	**13**	14.57	**11.44**	17	171	63	
63	144	13	**11.72**	14.86	15	**14**	15.05	**11.70**	17	188	61	
60	157	13	**11.98**	15.60	15.5	**15**	15.43	**11.95**	18	206	63	

* Speeds based on (Leger 88)

Leger Child VO2= 31.025 + (3.238 * Max speed) - (3.248 * age) + (0.1536 * max speed * age)

Appendix C: 15m to 20m PACER score conversion chart

PACER Conversion Chart

Use this chart to convert scores on the 15 M PACER to a 20 M score to enter in the FITNESSGRAM software.

Level	Laps																			
1	15 M	1	2	3	4	5	6	7	8	9										
	20 M	1	2	2	3	4	5	5	6	7										
2	15 M	10	11	12	13	14	15	16	17	18	19									
	20 M	8	8	9	10	11	12	12	13	14	15									
3	15 M	20	21	22	23	24	25	26	27	28	29	30								
	20 M	15	16	17	18	18	19	20	21	22	22	23								
4	15 M	31	32	33	34	35	36	37	38	39	40	41	42							
	20 M	24	25	25	26	27	28	28	29	30	31	32	32							
5	15 M	43	44	45	46	47	48	49	50	51	52	53	54							
	20 M	33	34	35	35	36	37	38	38	39	40	41	41							
6	15 M	55	56	57	58	59	60	61	62	63	64	65	66	67						
	20 M	42	43	44	45	45	46	47	48	48	49	50	51	51						
7	15 M	68	69	70	71	72	73	74	75	76	77	78	79	80						
	20 M	52	53	54	55	55	56	57	58	58	59	60	61	61						
8	15 M	81	82	83	84	85	86	87	88	89	90	91	92	93	94					
	20 M	62	63	64	65	65	66	67	68	68	69	70	71	72	72					
9	15 M	95	96	97	98	99	100	101	102	103	104	105	106	107	108					
	20 M	73	74	75	75	76	77	78	78	79	80	81	82	82	83					
10	15 M	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123				
	20 M	84	85	85	86	87	88	88	89	90	91	92	92	93	94	94				
11	15 M	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138				
	20 M	95	96	97	98	98	99	100	101	102	102	103	104	105	105	106				
12	15 M	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154			
	20 M	107	108	108	109	110	111	112	112	113	114	115	115	116	117	118	118			
13	15 M	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171		
	20 M	119	120	121	122	122	123	124	125	125	126	127	128	128	129	130	131	131		
14	15 M	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188		
	20 M	132	133	134	135	135	136	137	138	138	139	140	141	142	142	143	144	144		
15	15 M	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205		
	20 M	145	146	147	148	148	149	150	151	152	152	153	154	155	155	156	156	157		
16	15 M	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	
	20 M	158	159	160	161	162	162	163	164	165	165	166	167	168	168	169	170	171	171	
17	15 M	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	
	20 M	172	173	174	175	175	176	177	178	178	179	180	181	182	182	183	184	185	185	
18	15 M	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
	20 M	186	173	174	188	189	190	191	192	192	193	194	195	195	196	197	198	198	199	200
19	15 M	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279
	20 M	201	173	174	203	204	205	205	206	207	208	208	209	210	211	212	212	213	214	215
20	15 M	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298
	20 M	216	216	217	218	218	219	220	221	222	222	223	224	225	225	226	227	228	228	229

Appendix D: 15m PACER recoding sheet

15 Meter PACER Recording Sheet

Level	Laps																	
1	1	2	3	4	5	6	7	8	9									
2	10	11	12	13	14	15	16	17	18	19								
3	20	21	22	23	24	25	26	27	28	29	30							
4	31	32	33	34	35	36	37	38	39	40	41	42						
5	43	44	45	46	47	48	49	50	51	52	53	54						
6	55	56	57	58	59	60	61	62	63	64	65	66	67					
7	68	69	70	71	72	73	74	75	76	77	78	79	80					
8	81	82	83	84	85	86	87	88	89	90	91	92	93	94				
9	95	96	97	98	99	100	101	102	103	104	105	106	107	108				
10	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123			
11	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138			
12	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154		
13	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	
14	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	
15	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206

Location ______________

Date ______________

Trial ______________

Recorder ______________

Name / ID #	Jersey #	Laps

Name / ID #	Jersey #	Laps

Name / ID #	Jersey #	Laps

Name / ID #	Jersey #	Laps

Appendix E: 20m PACER recording sheet

20 Meter PACER Recording Sheet

Level	Laps												
1	1	2	3	4	5	6	7						
2	8	9	10	11	12	13	14	15					
3	16	17	18	19	20	21	22	23					
4	24	25	26	27	28	29	30	31	32				
5	33	34	35	36	37	38	39	40	41				
6	42	43	44	45	46	47	48	49	50	51			
7	52	53	54	55	56	57	58	59	60	61			
8	62	63	64	65	66	67	68	69	70	71	72		
9	73	74	75	76	77	78	79	80	81	82	83		
10	84	85	86	87	88	89	90	91	92	93	94		
11	95	96	97	98	99	100	101	102	103	104	105	106	
12	107	108	109	110	111	112	113	114	115	116	117	118	
13	119	120	121	122	123	124	125	126	127	128	129	130	131
14	132	133	134	135	136	137	138	139	140	141	142	143	144
15	145	146	147	148	149	150	151	152	153	154	155	156	157

Location ______________

Date ______________

Trial ______________

Recorder ______________

Name / ID #	Jersey #	Laps

Name / ID #	Jersey #	Laps

Name / ID #	Jersey #	Laps

Name / ID #	Jersey #	Laps

Appendix F: Extended Literature Review

Laboratory measurement of VO_2max by direct calorimetery is well accepted as the criterion standard for aerobic capacity assessment. However, due to the high cost of the equipment necessary for testing and the time required for individual assessment, this type of procedure is not practical for fitness assessment on large populations, such as those in an educational environment. Field tests have been developed and are essential for estimating aerobic capacity outside of the laboratory. Field tests for aerobic capacity must be valid, reliable, easily administered, allow simultaneous assessment, require minimal equipment, and be non-invasive in nature. All of the major physical fitness assessment batteries in the United States include an assessment of aerobic capacity using a field test measure.

FITNESSGRAM is a comprehensive health-related physical fitness and activity assessment battery for children, which is administered by many school physical education programs across the United States (*FITNESSGRAM* Test Administration Manual 3rd Ed., 1999). *FITNESSGRAM* includes health-related physical fitness assessments for aerobic capacity, body composition, muscular strength, muscular endurance, and flexibility. Test administrators may select between two field test protocols for aerobic capacity, the Mile Run and the Progressive Aerobic Cardiovascular Endurance Run (PACER) test. A unique aspect of *FITNESSGRAM* is the use of criterion-referenced standards (CRF) that determine how fit children need to be for health. This review will describe the protocols and the validity / reliability for both the Mile Run and the PACER.

Mile Run Test

Mile Run Description

The Mile Run test protocol consists of participants running one mile at a maximal sustainable pace. A prediction equation is used to estimate maximal oxygen uptake (VO_2max) from the mile run time (Cureton et al, 1995). The equation uses age in years, sex (coded 0 for women and 1 for men), body mass index (BMI in units of Kg m^{-2}), and mile run time (minutes) for the prediction of treadmill VO_2peak in ml kg^{-1} min^{-1} [VO_2max = 0.21 (Age *Sex) – 0.84 (BMI) – 8.41 (Time) + 0.34 ($Time^2$) + 108.94].

The major benefit of the Mile Run is that it can be easily administered to large groups simultaneously. The equipment required to administer the Mile Run test is a stopwatch, a marked track or a measuring wheel, and a large open area to mark a course. There are several problems with the mile run. To accurately assess aerobic capacity the student has to give a maximal effort throughout the duration of the test, which is difficult for many students and leads to low participant motivation. Children who are not accustomed to distance running often have difficulty pacing running speed appropriately throughout the test. Also, many schools do not have direct access to the facilities or the area necessary to perform the test.

Mile Run Validity

The Mile Run test was validated against the criterion standard treadmill VO_2max measured in ml kg^{-1} min^{-1} by a number of earlier studies in the late 1970's. In 1977, Krahenbuhl et al. reported correlations between measured VO_2 max and mile run time (minutes) in eight year old children of r = -0.71 (males) and r = -0.26 (females). The correlation for all subject was r = -0.62 (n = 38). Cureton et al. reported similar correlations between measured VO_2max and mile run time (minutes) for children 7 to 12 years old. The correlation for all subjects was r = -0.66 (n = 196). In 1978, Krahenbuhl reported correlations between measured VO_2max and 1600 meter run time (minutes) for 1st, 2nd and 3rd grade students. The correlations were r = -0.60 for males and r = -0.74 for females.

More recently, Buono et al. reported correlations between measured VO_2max and mile run time (seconds) for 5th, 8th, and 11th grade students. Correlations ranged from r = -0.76 (5th grade) to r = -0.85 (11th grade). The correlation for all subjects was r = -0.73 (n = 90). In 1995, Cureton et al. conducted a comprehensive study to estimate aerobic capacity from mile run times. In this study they collected data from 753 males and females age 8 to 25. The sample was split into a validation group (n=495) and cross validation group (n=258). A VO_2max prediction equation was determined by regression analysis from the validation group and no difference was detected between estimated and actual levels of fitness with cross validation. All subjects (N=753) data were used for the published regression equation with a resulting multiple correlation of R = 0.71 and standard error of estimate (SEE) of 4.8 ml kg^{-1} min^{-1}. This VO_2max prediction equation is currently used in the *FITNESSGRAM* assessment battery for the mile run. Overall, validation studies comparing mile run time and VO_2max expressed in ml kg^{-1} min^{-1} have had variable results but generally have reported moderate correlations between r = -0.60 to r = -0.85. Table 1F provides a summary of the reported validity coefficients and SEE values for the mile run.

Table 1F Concurrent validity of the One-Mile Run test in children, adolescents and college students [Adapted from FITNESSGRAM Reference Guide (2001)]

Source	Sample	Validity Coefficient	SEE ($ml \times kg^{-1} \times min^{-1}$)
Bono et al. (1991)	15 M & 15 F, 5^{th} grade	-.76	4.6
	15 M & 15 F, 8^{th} grade	-.80	4.9
	15 M & 15 F, 11^{th} grade	-.85	4.3
	45 M & 45 F, 5-11^{th} grade	-.73	5.3
	45 M & 45 F, 5-11^{th} grade	-.84[a]	4.3
Cureton et al. (1977)	140 M & 56 F, 7-11^{th} grade	-.66	4.9
Cureton (1995)	490 M & 263 F, 8-25 yrs.	.72[b]	4.8
Krahenbuhl et al. (1978)	49 M, grades 1-3	-.60[c]	5.1
	34 F, grades 1-3	-.74[c]	4.4
Krahenbuhl et al. (1977)	38 M & F, 3^{rd} grade	-.62[d]	5.3
	18 F, 3^{rd} grade	-.26[d]	5.5
	20 M, 3^{rd} grade	-.71[d]	5.0
Plowman and Liu (1999)	94 M & F, 18-30 yrs.	.82[e]	4.6

[a] Prediction from age, gender, weight, sum of two skinfolds, and one-mile run/walk
[b] Prediction from age x gender, BMI, MRW (Mile Run/Walk), and MRW^2
[c] 1600-m run
[d] 1609-m run
[e] Correlation between VO2max predicted from using Cureton et al. (1995) equation and measured VO2max

Mile Run Reliability

The test-retest reliability of the mile run has been assessed in school age children by several studies. In 1978, Krahenbuhl et al. reported interclass correlation coefficients for test-retest reliability in 1^{st} through 3^{rd} grade students ranging from a high of r =0.918 for third grade males to a low of r = 0.824 for first grade females. In 1991, Buono et al. reported interclass correlation coefficients for test-retest reliability in 5^{th}, 8^{th}, and 11^{th} grade students. Reliability coefficients ranged from a low of r = 0.91 (5^{th} grade) to a high of r = 0.95 (11^{th} grade). The correlation for all subjects was r = 0.95 (n = 90). In 1992, Rikli et al. reported intraclass correlation coefficients for both fall and spring test-retest reliability separated by one week in kindergarten through 4th grade students. Test-retest reliability generally increased with age from kindergarten through 4th grade and ranged from a low of R= 0.53 to a high of R= 0.90. The reliability of the mile run tends to increase with age and is generally high for school age children with the exception of the lowest grade levels. For children in third grade or beyond, reported reliability coefficients have ranged from R = 0.84 to r = 0.98. Table 2F provides a summary of the reported reliability coefficients for the mile run.

Table 2F. Reliability of the One-Mile Run test in children and adolescents [Adapted from FITNESSGRAM Reference Guide (2001)]

Source	Sample	Reliability Coefficient
Bono et al. (1991)	15 M & 15 F, 5th grade	r = .91
	15 M & 15 F, 8th grade	r = .93
	15 M & 15 F, 11th grade	r = .98
Krahenbuhl et al. (1978)	34 F, 1st grade	r = .82[a]
	49 M, 3rd grade	r = .92[a]
Rikli et al. (1992)[b]	20 M & 16 F, Kindergarten	R = .53, .39
	15 M & 17 F, 1st grade	R =.56, .54
	45 M & 52 F, 2nd grade	R =.70, .71
	53 M & 63 F, 3rd grade	R =.84, .90
	44 M & 37 F, 4th grade	R =.87, .85

Notes. r = interclass reliability; R = intraclass reliability for a single trial
[a]1600-m run
[b] First coefficient is for males, second is for females

PACER Test

PACER Description

The PACER test consists of running a 20-meter shuttle course with 1-minute paced stages at an initial running speed of 8.5 km $h^{-1}$and speed increasing 0.5 km h^{-1} per stage (Leger et al., 1988). A prediction equation is used to convert PACER performance to VO_2max (ml kg^{-1} min^{-1}). The equation uses age (rounded to the lower integer), maximum running speed, and an interaction of age and running speed to estimate VO_2max for children age 8-18 [VO_2 = 31.025 + (3.238 * max speed) - (3.248 * age) + (0.1536 * max speed * age)] (Leger et al., 1988). The PACER can be administered in groups of 10-20 students. The equipment required to administer the test is an open 20-meter area and a CD player.

The PACER assessment protocol has several advantages over other distance running protocols. The protocol can be performed inside which eliminates environmental limitations and influences on testing. The test eliminates participant responsibility for selecting an appropriate pace by using an audio CD with tones indicating required running pace. Additional benefits of the testing protocol are that participants run together until drop out instead of having subjects clearly ahead or behind, and the last person to complete the test preformed best as opposed to worst (Vincent et al., 1999). The PACER protocol is progressive in nature allowing much of the test to be preformed at a submaximal sustainable effort. Only the final stages would require a maximal effort from the participant. These factors help to reduce stress and motivational concerns associated with fitness testing. Because of these unique advantages, the PACER is the recommended test for aerobic capacity in the *FITNESSGRAM* assessment battery (*FITNESSGRAM* Test Administration Manuel 2nd Ed., 1999).

PACER Validity

The PACER test has been validated against the criterion standard VO_2max measured in ml kg^{-1} min^{-1} in several studies. The initial protocol for the 20 meter shuttle test (20-MST) utilized two minute stages (Leger et al., 1982). However, two minute stages were found to be psychologically boring for children and the test was modified to use one minute stages (Leger et al., 1988). In 1988, Leger et al. validated the maximum achieved running speed from the 20-MST with one minute stages against VO_2max determined by retroextrapolating from the 0_2 recovery curve. A correlation coefficient of 0.71 and SEE of 5.9 ml kg^{-1} min^{-1} or 12.1% was reported from a sample of 188 boys and girls age 8-19 who were tested individually. Van Mechelen et al. reported the correlation between the highest running stage achieved and treadmill VO_2max in children age 12 to 14 of $r = 0.68$ (boys) and $r = 0.69$ (girls). The correlation for all subjects was $r = 0.76$ ($n = 82$, SEE = 4.4 ml kg^{-1} min^{-1}).

Three studies reported the correlation between number of laps completed and treadmill VO_2max. Boreham et al. (1990) reported correlations on 15-year-old school children ranging from $r = 0.64$ (boys) to $r = 0.90$ (girls). The correlation for all subjects was $r = 0.87$ ($n = 41$). Mahoney reported correlations on 12-year-old school children (Mahoney, 1992). Correlations in this study were higher for boys ($r = 0.83$) than girls ($r = 0.76$) but the sample sizes were smaller (10 and 8, respectively). Liu et al. (1992) reported correlations between laps and treadmill VO_2max on 12 to 15 year old students, and also sought to validate the prediction equation for VO_2max reported by Leger et al. in 1988. Correlations in this study were similar for boys ($r = 0.65$) and lower for girls ($r = 0.51$). The correlation for all subjects was $r = 0.69$ ($n = 41$). When estimated VO_2max (48.72 ± 5.72 ml kg^{-1} min^{-1}) was compared with the measured VO_2peak (49.97 ± 7.59 ml kg^{-1} min^{-1}) there was no significant difference, t (47) = -1.631; $p \geq 0.11$. A correlation between the means resulted in a coefficient of r = 0.72 and SEE of 5.26 ml kg^{-1} min^{-1}. Overall, tests of validity of the 20-MST that correlated treadmill VO_2max with either maximum running speed, number of levels completed, or number of laps completed have reported moderate to high correlation coefficients between r = 0.51 and r = 0.87. Table 3F provides a summary of the reported validity coefficients and SEE values for the PACER.

Table 3F. Concurrent validity of the PACER test in children and adolescents [Adapted from FITNESSGRAM Reference Guide (2001)]

Source	Sample	Validity Coefficient	SEE ($ml \times kg^{-1} \times min^{-1}$)
Armstrong et al. (1988)	77 M, 11-14 y	.54	5.3
Barnett et al. (1993)	27 M & 28 F, 12-17y	.74	4.6
		.82[b]	4.0
		.85[c]	3.7
		.72[a]	5.4
Boreham et al. (1990)	23 M, 14-16 y	.64	4.5
	18 F, 14-16 y	.90	2.5
	23 M & 18 F, 14-16 y	.87	3.9
Leger et al. (1988)	188 M & F, 8-19 y	.71	5.9
Liu et al. (1992)	22 M, 12-15 y	.65	5.3
	26 F, 12-15 y	.51	5.2
	48 M & F, 12-15 y	.69	5.5
	48 M & F, 12-15 y	.72[a]	5.3
Mahoney (1992)	10 M, 12 y	.83	UR
	8 F, 12y	.76	UR
van Mechelen et al. (1986)	41 M, 12-14 y	.68	4.0
	41 F, 12-14 y	.69	3.5
	82 M & F, 12-14 y	.76	4.4

[a]Cross-validation of the Leger et al. (1988) equation
[b]Prediction from age, sex, and maximal shuttle speed
[c]Prediction from triceps skinfold, sex, and maximal shuttle speed
[d]Correlated half stages completed and treadmill VO_2max
UR = unreported

PACER Reliability

The test-retest reliability of the PACER has been assessed in school age children by several studies. All of these studies had subjects perform the 20-MST on two separate occasions separated by one week. In 1988, Leger et al. reported the first reliability coefficients for the current PACER protocol. The interclass reliability coefficient for boys and girls age 8 to 16 was R=0.89 (n = 139). Several other studies have reported intraclass reliability coefficients on the PACER. In 1992, Liu et al. reported correlations on 12 to 15 year old students ranging from R= 0.91 (boys) to R= 0.87 (girls). The correlation for all subjects was R= 0.93 (n = 20). Mahoney (1992) reported correlations in 12 year old students that were similar for girls (R= 0.88) and lower for boys (R= 0.73). In 1999, Vincent reported intraclass reliability on a sample of 5th grade students, reliability coefficients ranged from R= 0.75 (girls) to R= 0.79 (boys). The correlation for all subjects was R= 0.82 (n=51). The reported test-retest reliability of the PACER protocol in school age children is generally high and ranges from r = 0.82 to r = 0.93. Table 4F provides a summary of the reported reliability coefficients for the PACER.

Table 4F. Reliability of the PACER test in children and adolescents [Adapted from FITNESSGRAM Reference Guide (2001)]

Source	Sample	Reliability Coefficient
Dinschel (1994)	57 M & 44 F, 4-5th grade	R = .84
Leger et al. (1988)	139 M & F, 6-16 y	r = .89

Liu et al. (1992)	20 M & F, 12-15 y	R = .93
Mahar et al. (1997)	137 M & 104 F, 10-11 y	R = .90
Mahoney (1992)	12 M, 12y	R = .73
	8 F, 12y	R = .88
Vincent et al. (1997)	29 M & 22 F, 5th grade	R = .82

Note: r = interclass reliability; R = intraclass reliability for a single trial

Criterion Referenced Standards for Fitness Tests

In the past, health fitness tests performance was typically evaluated by comparing the participant's fitness level to normative standards from a well-defined peer reference group. The advantage of normative referenced standards is that children are able to see how they compare to other children of the same age and gender across the country. The disadvantage to normative referenced standards is they do not provide information on health status of the participant. The FITNESSGRAM assessment battery utilizes health related criterion-referenced standards. A health-related criterion-referenced standard represents a desirable level of health that should be attainable by the majority of the population with adequate physical activity (Blair, 1985). Criterion-referenced standards for health related physical fitness test are linked to good health status and reduced disease risk.

There are two requirements that must be met to determine if a criterion-referenced measure is valid. Individuals who meet the criterion measure must achieve the criterion score on the field test, and individuals who fail to meet the criterion measure also fail to achieve the criterion score on the field test (*FITNESSGRAM* Reference Guide, 2001)

Summary

Overall, tests of validity for the PACER and the mile run have reported moderate correlation with VO_2 max. Reliability coefficients reported for both assessments have demonstrated high correlations as well. Although both the PACER test and the mile run are acceptable field assessments of aerobic capacity, the PACER assessment protocol has several advantages for youth fitness testing. One of the major benefits is the ability to perform the test indoors. However, many schools have gyms or physical education classrooms that are not 20 meters in length. The development of a shorter length PACER protocol would result in a more versatile field test by accommodating smaller facilities.

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