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The Reliability and Validity of the 20-Meter Shuttle Test in American Students 12 to 15 Years Old

Nora Y.-S. Liu, Sharon A. Plowman, and Marilyn A. Looney

The purpose of this study was threefold: to determine (a) the test-retest reliability of the 20-meter shuttle test (20 MST) (number of laps); (b) the concurrent validity of the 20 MST (number of laps); and (c) the validity of the prediction equation for \( VO_2 \) max developed by Léger, Mercier, Gadoury, and Lambert (1988) on Canadian children for use with American children 12-15 years old. An intraclass coefficient of .93 was obtained on 20 students (12 males; \( R = .91 \) and 8 females; \( R = .87 \)) who completed the test twice, 1 week apart (\( M_{20} = 47.80 \pm 20.29 \) vs. \( M_{29} = 50.55 \pm 22.39 \) laps; \( p \geq .13 \)). \( VO_2 \) peak was obtained by a treadmill test to volitional fatigue on 48 subjects. The number of laps run correlated significantly with \( VO_2 \) peak in males (\( n = 22; \ r = .65 \); \( F [1, 20] = 14.30; p \leq .001 \), females (\( n = 26; \ r = .51 \)); \( F [1, 24] = 8.34; p < .001 \), and males and females (\( r = .69 \); \( F [1, 46] = 42.54; p < .001 \)). When the measured \( VO_2 \) peak (\( M = 49.97 \pm 7.59 \) \( ml.kg^{-1}.min^{-1} \)) was compared with the estimated \( VO_2 \) max (\( M = 48.72 \pm 5.72 \) \( ml.kg^{-1}.min^{-1} \)) predicted from age and maximal speed of the 20 MST (Léger et al., 1988) no significant difference was found, \( t (47) = -1.63; p = .11 \), between the means; the \( r \) was .72 and SEE was 5.26 \( ml.kg^{-1}.min^{-1} \). It was concluded that (a) the 20 MST is a reliable test, (b) the 20 MST is as valid a test of cardiorespiratory endurance as other distance run tests for this age group, and (c) the Léger et al. (1988) prediction equation for \( VO_2 \) max is valid for 12-15-year-old American youths.

Key words: aerobic capacity, children, exertion, physical fitness test

All of the major health-related physical fitness test batteries currently being used in the United States include a distance run as an indication of cardiovascular-respiratory endurance or aerobic capacity. Most batteries (AAHPERD Physical Best, [AAHPERD, 1988]; FITNESSGRAM [Institute for Aerobics Research, 1987]; President’s Physical Fitness Test [President’s Council on Physical Fitness and Sport, 1987]; YMCA Youth Fitness Test [Franks, 1989]) employ the mile or mile and a half run (or the equivalent 9- or 12-min runs), whereas others (Chrysler-AAU [Chrysler Fund-Amateur Athletic Union, 1987]; National Children and Youth Fitness Test [Ross & Gilbert, 1985; Ross & Pate, 1987]) include shorter distances for young children, and one (Fit Youth Today [American Health and Fitness Foundation, 1986]) employs a 20-min steady-state jog. Increasing attention is being paid, however, in Canada and Europe, to a 20-m shuttle test (20 MST).

The 20 MST is included in EUROFIT (Council of Europe, Committee for the Development of Sport, 1988), and the Canadians have recently developed national norms for youngsters 6 to 17 years old (Massicotte, 1990).

The 20 MST was developed by Léger and Lambert (1982) to simulate a graded exercise test with approximately one MET level increase between stages. Rather than running around an oval track, subjects run back and forth between parallel lines placed 20 m apart. Because no grade can be involved as on a treadmill, the energy demand is elevated by increasing the speed. The test originally was divided into 2-min stages, but these were subsequently shortened to 1 min.

The 20 MST appears to have several practical advantages over the traditional distance runs. It can be administered in a relatively small space either indoors or outdoors and is therefore practical for schools without extensive facilities. For those whose sports involve frequent stops, starts, and turns, it may be a more specific test than a continuous directional run. Problems associated with learning pace are eliminated, as pace is controlled throughout. The test is incremental and hence submaximal for much of its duration, requiring maximal effort only the last minute or so. For this reason it does not require maximal motivation throughout. This should reduce, if not eliminate, the influence that average \( %VO_2 \) max used during the test has on the results. Per-

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The speed begins at 8.5 km·h⁻¹, which is sufficient for American students 12–15 years old, whereas VO₂max is the most important determinant in 12–15-year-old youngsters (McCormack, Cureton, Bullock, & Weyand, 1991). Finally, the more rather than the less fit students finish last, which may eliminate a psychological burden for the less fit.

The critical questions, however, concern the reliability and validity of the test. Several studies have been conducted in this area (Armstrong, Williams, & Ringham, 1988; Boreham, Paliczka, & Nichols, 1990; Légére, Mercier, Cadoury, & Lambert, 1988; van Mechelen, Hobil, & Kemper, 1986). None of these studies on children or adolescents, however, have been conducted on American youngsters. Because there is little agreement concerning the fitness status of American youth (Looney & Plowman, 1990) and no recent data directly comparing American and Canadian or European youngsters, it is necessary to obtain technical information on the 20 MST on American students before recommending its use.

The purpose of this study was threefold: to determine (a) the test-retest reliability of the 20 MST (number of laps) in American students 12–15 years old; (b) the concurrent validity of the 20 MST (number of laps) in American students 12–15 years old; and (c) the validity of the prediction equation for VO₂max developed by Légére et al. (1988) on Canadian children and adolescents for use with American adolescents in this age range.

Method

Subjects

Sixty-two students between the ages of 12 and 15 years volunteered as subjects. Twenty (12 males and 8 females) participated in the test-retest reliability study. Forty-eight subjects participated in the validity study. Six subjects (2 males and 4 females) took part in both the reliability and validity testing sessions. All subjects and a parent or guardian gave informed consent prior to testing.

20 MST Protocol

The 20 MST consists of 1-min stages (called levels) of continuous incremental pace running (Légére et al., 1988). The speed begins at 8.5 km·h⁻¹ and increases 0.5 km·h⁻¹ at each successive minute, reaching 18.0 km·h⁻¹ at minute 20. Subjects run 20 m (designated as a lap or "shuttle"), turn, and run back in time with auditory signals from a prerecorded tape. Each emitted sound indicates that the subject should be touching one or the other of the parallel lines placed 20 m apart. Each level is announced on the tape. Because the time and distance are constant but the pace varies, the number of shuttles (or laps) varies at most levels (or minutes). When a subject stops or fails to get within approximately 3 m of an end line two consecutive times, that shuttle (lap) is recorded and the test ends. Because of the greater exactness, the number of shuttles (laps), not level or speed attained, were used for statistical analysis in this study. Subjects were asked to go to the point of volitional fatigue and were verbally encouraged to do so.

Test-retest reliability data were collected at St. Aloysius Elementary School and Bowling Green Junior High School in Bowling Green, Ohio, one week apart. Between 10 and 15 students were tested at one time to simulate the way in which a physical education teacher would utilize the test. Those who took the 20 MST for the validity study were tested individually on the day they reported to the Human Performance Laboratory at Bowling Green State University prior to the maximal treadmill test. Students were given as much rest time between the two tests as they wanted or the option to return on another day for the treadmill test. None elected that option. At least 30 min of rest occurred between the 20 MST and the treadmill test. Bar-Or (1988) has noted the fast recovery of children after maximal tests, and van Mechelen et al. (1986) found no sequential effect when the 20 MST and treadmill test were randomized. All testing was done by one of the investigators.

Laboratory Testing

Subjects were weighed to the nearest 0.25 lb (0.11 kg), and height was measured to the nearest 0.5 inch (1.27 cm) on a Detecto Medic Scale. These values were converted to metric units. Body mass index (BMI) was computed as weight (kg) divided by height (m) squared (wt/ht²).

All subjects were given preliminary instructions on how to walk on the treadmill and were allowed to practice. A warm-up period of 3 min (4.8 km·h⁻¹), 0% grade for 2 min; 4 mph (6.4 km·h⁻¹), 2.5% grade for 2 min; and either 5 mph (8 km·h⁻¹), 5% grade (females) or 6 mph (9.6 km·h⁻¹), 5% grade (males) for 1 min preceded the data collection. The treadmill protocol began at a speed of 5 mph (8 km·h⁻¹) for females and 6 mph (9.6 km·h⁻¹) for males, with a grade of 5% for both males and females. The grade was kept constant throughout the test, while the speed increased 1 mph (1.61 km·h⁻¹) every 3 to 5 min depending on the response of the subject. The test was performed on a Quinton Model 65 treadmill. Metabolic data were collected and analyzed by a Sensormedics 2900 Metabolic Measurement Cart. The oxygen and carbon dioxide analyzers were calibrated prior to each test against gases of known composition. Metabolic data were computed and printed at 20-s intervals. Heart rate was measured by a Polar Heart Rate Monitor and recorded each minute. Because of the difficulty of using adult criteria to determine maximal oxygen consumption in children...
and young adolescents (Cunningham, Van Waterschoot, Paterson, Lefcoe, & Sangal, 1977; Krahenbuhl, Skinner, & Kohrt, 1985; Rowland, 1989), the highest attained VO\textsubscript{2} value at the point of volitional fatigue was taken as the VO\textsubscript{2} peak.

Statistical Analyses

Test–retest reliability was determined by an intraclass correlation coefficient (one-way ANOVA model for a single trial) for males \((n = 12)\) and females \((n = 8)\) together \((M\text{ age } = 13.8 \pm 0.7\, \text{ year})\). Independent \(t\)-tests were utilized to determine significant differences between males and females on all variables. Concurrent validity of the 20 MST was determined by the correlation coefficient between the number of laps (shuttles) and measured VO\textsubscript{2} peak. The error in predicting VO\textsubscript{2} max from the number of laps (shuttles) completed and VO\textsubscript{2} peak \((\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1})\) is presented in Figure 1. The number of laps run correlated significantly with VO\textsubscript{2} peak in males \((n = 22; r = .65; F[1, 20] = 14.30; p < .001)\), females \((n = 26; r = .51; F[1, 24] = 8.34; p < .01)\), and males and females together \((r = .69; F[1, 46] = 42.54; p < .001)\).

The validation analyses of Léger et al.’s (1988) equation appear in Table 2. No significant difference was found between the measured VO\textsubscript{2} peak and estimated VO\textsubscript{2} max means, \(t(47) = -1.63; p > .11\). The correlation between the two values was .72, the \(\text{SEE} = 5.27\), the Error was 5.40 ml·kg\(^{-1}\)·min\(^{-1}\), and 81.3% of the measured VO\textsubscript{2} peak values fell within 5.9 ml·kg\(^{-1}\)·min\(^{-1}\) of the estimated VO\textsubscript{2} max.

Discussion

The results of previous studies on the reliability and concurrent validity of the 20 MST conducted on children and adolescents are included in Table 3. The only other test–retest reliability value was .89 (Léger et al., 1988), and although it appears this is an interclass coefficient, this is comparable to the .93 attained in this study. In both studies there was no significant difference between the \(T_1\) and \(T_2\) means. Léger et al. used maximal speed whereas this study reported laps. Both the mean values of 47.80 and 50.55 laps occur in minute 6 and hence at the same speed. This means there

<table>
<thead>
<tr>
<th>Table 1. Subject characteristics and data for validation study ((M \pm SD))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
</tr>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Weight (kg)</td>
</tr>
<tr>
<td>BMI (wt/ht(^2))</td>
</tr>
<tr>
<td>HR(_\text{max}) (b/min(^{-1}))</td>
</tr>
<tr>
<td>RER(^*)</td>
</tr>
<tr>
<td>VO\textsubscript{2} peak (ml·kg(^{-1})·min(^{-1}))</td>
</tr>
<tr>
<td>20-m shuttles (no. of laps)</td>
</tr>
</tbody>
</table>

\(^*\text{RER = respiratory exchange ratio, VO}_2\text{ produced/VO}_2\text{ consumed.}\)

\(p < .0001\), male > female.
is neither a statistical nor a practical difference between the number of laps.

A list of the reliabilities for the traditional distance run tests (600 yd, 1,600 m, 9 and 12 min) in children and adolescents by Safrit (1990) shows a range from .61 to .94 with those in the 12–15-year age group spanning this entire range. Comparatively, the reliability of the 20 MST is at least as good as, if not better than, other currently used run tests of cardiovascular-respiratory endurance in adolescents.

Because distance runs are considered a measure of cardiovascular-respiratory capacity they are validated against the criterion measure of VO₂max, preferably obtained during an incremental test on the treadmill.

<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects</th>
<th>Criterion VO₂ test</th>
<th>20 MST Variable used</th>
<th>Validity</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>van Mechelen</td>
<td>41 M, 41 F</td>
<td>TM 8 km·h⁻¹ level</td>
<td>.88 M</td>
<td>.68 M</td>
<td>.89 F</td>
</tr>
<tr>
<td>et al. (1988)</td>
<td>12–14 years</td>
<td>2.5% ↑ /2 min</td>
<td></td>
<td>.70 M &amp; F</td>
<td></td>
</tr>
<tr>
<td>Armstrong</td>
<td>77 M</td>
<td>TM 10 km·h⁻¹ %</td>
<td>½ level</td>
<td>.54</td>
<td></td>
</tr>
<tr>
<td>et al. (1988)</td>
<td>11–14 years</td>
<td>2% ↑ /3 min stages discontinuous</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Léger</td>
<td>188 M+F</td>
<td>retroextrapolation at end of 20 MST</td>
<td>max speed</td>
<td>.71 M &amp; F</td>
<td></td>
</tr>
<tr>
<td>et al. (1988)</td>
<td>9–19 years</td>
<td></td>
<td></td>
<td>.89</td>
<td></td>
</tr>
<tr>
<td></td>
<td>139 M+F</td>
<td>8–16 yr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boreham</td>
<td>23 M, 18 F</td>
<td>TM 8, 8, 10 km·h⁻¹ number of laps</td>
<td>.84 M</td>
<td>.93 M &amp; F</td>
<td></td>
</tr>
<tr>
<td>et al. (1990)</td>
<td>14–18 years</td>
<td>then 2% ↑ /min</td>
<td></td>
<td>.87 F</td>
<td>.87 M &amp; F</td>
</tr>
<tr>
<td>Liu</td>
<td>12 M, 8 F</td>
<td>Incremental number of laps</td>
<td>.65 M</td>
<td>.93 M &amp; F</td>
<td></td>
</tr>
<tr>
<td>et al. (current study)</td>
<td>12–15 years</td>
<td>TM</td>
<td>.51 F</td>
<td>.87 F</td>
<td>.91 M</td>
</tr>
</tbody>
</table>

Note. M = males; F = females.
tered together and the 42% accounted for in the male only group are both slightly higher. Thus, although the current results are somewhat lower than other values for the 20 MST, they are at least as good as those of other distance runs commonly utilized.

The prediction equation of Léger et al. (1988) is the only one currently available in the literature to convert 20 MST data to VO$_2$max (ml·kg$^{-1}$·min$^{-1}$) for children and adolescents 8–19 years old. The ability to convert 20 MST results to VO$_2$max values with an acceptable error could be extremely practical. For example, it is difficult to know what time on a mile run is equivalent to laps (shuttles) completed on the 20 MST. However, if the results of both tests can be reasonably converted to VO$_2$max (ml·kg$^{-1}$·min$^{-1}$) a comparison can be made between tests and against established VO$_2$max norms or criterion-referenced standards.

Validation of the estimated VO$_2$max from Léger et al.’s (1988) multiple regression equation with the actual measured VO$_2$peak showed close agreement between the means (Table 5), reasonable errors, and a high percentage of measured VO$_2$peak values falling within 5.9 ml·kg$^{-1}$·min$^{-1}$ of the estimated VO$_2$max values. The correlation of .72 between measured VO$_2$peak and estimated VO$_2$max achieved in this study is almost identical to the correlation of .71 reported by Léger et al. in the original study between 20 MST results and measured VO$_2$max. It should be noted that Léger et al. obtained their VO$_2$max values from the 20 MST by retroextrapolation of recovery O$_2$ and not from a maximal treadmill test. The SEE is comparable to those reported for other modalities and variables used to predict VO$_2$max (approximately 4–7 ml·kg$^{-1}$·min$^{-1}$) (Conley, Cureton, Dengel, & Weyand, 1991). Thus the use of this prediction equation to convert 20 MST results to an estimated VO$_2$max value appears to be valid in this age group. More research needs to be done across the total age range to judge the acceptability of the prediction equation.

It is concluded that the 20 MST is a reliable test. The 20 MST is as least as valid a field test for cardiovascular-respiratory endurance as other distance run tests for males and females 12–15 years of age. Léger et al.’s (1988) regression equation can be used to estimate VO$_2$max within an acceptable range of error in this age group. It is recommend that the 20 MST be considered as an alternative test for inclusion in physical fitness batteries for school children in this age range.

References


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**Authors’ Notes**

The order of the first two authors is alphabetical and does not indicate a lesser role for either author. This study was partially supported by a Bowling Green State University Faculty Research Grant.