Validity of 20-MST for predicting $\dot{V}O_{2\text{max}}$ of adult Singaporean athletes

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This investigation compared the results of direct and indirect measurements of maximum oxygen uptake ($\dot{V}O_{2\text{max}}$) of an Asian population. Twenty subjects (16 male, 4 female), all of whom were physical education students, were assessed directly using laboratory treadmill running to determine $\dot{V}O_{2\text{max}}$. The indirect estimation of $\dot{V}O_{2\text{max}}$ was obtained using a modified form of the Leger and Lambert 20-m multistage shuttle run test (20-MST). Heart rates were recorded throughout both tests. Pearson product moment correlations confirmed test–retest reliability for both direct and indirect measurements ($r = 0.90$ and $r = 0.91$ respectively). Differences for test–retest were found to be not significant. No differences were found between the maximal heart rate responses of the subjects for the direct and indirect tests. Of the subjects 75% had a lower predicted $\dot{V}O_{2\text{max}}$ value ($P < 0.01$) compared with results gained by direct measurements when the Ramsbottom norms for the 20-MST were used. The reasons for this difference could be due to the different racial groups used as subjects, the climatic conditions in Singapore, or the small sample size. In order for the 20-MST test to be considered a valid measure of aerobic fitness in Singapore with an Asian population further study is recommended.

Keywords: Eurofit, 20-MST, $\dot{V}O_{2\text{max}}$, fitness, environment, active Asian adults

Aerobic fitness is a major component of fitness for good health as well as for optimal performance in many sports. Aerobic fitness is best described as the maximum oxygen uptake ($\dot{V}O_{2\text{max}}$) of an individual. However, laboratory tests are both expensive and impractical in many cases. There is a need for inexpensive, reliable and valid field tests to determine an estimate of $\dot{V}O_{2\text{max}}$ that are simple to administer and suitable for use with large groups of subjects.

Following the research of Leger and Lambert\(^1\) the 20-m multistage fitness test (20-MST) was adopted by the Council of Europe\(^2\) as one of its cardiorespiratory and motor fitness tests for assessing the physical development of schoolchildren. The test was modified by Ramsbottom et al.\(^3\) ($r = 0.92$, $P < 0.01$) for use by active adult sportsmen and sportswomen. Further, research has focused on validity testing\(^4\) by comparing physical working capacity and 20-MST tests of aerobic fitness in adolescent schoolchildren\(^5\) and investigating the 20-MST as a predictor of running performance and $\dot{V}O_{2\text{max}}$ in adults\(^6\).

The 20-MST has not been validated using an Asian population. It has been well documented that $\dot{V}O_{2\text{max}}$ as measured during laboratory treadmill testing, is not impaired in a hot environment with acclimatized subjects\(^7\). The purpose of this present study was to investigate the validity of predicting the $\dot{V}O_{2\text{max}}$ of Asian adult subjects from performance on the 20-MST in a hot and humid environment. This study was undertaken to examine the suitability of the 20-MST for use with the secondary school population in Singapore.

Subjects and methods

Sixteen men and four women students (15 Chinese, three Malay and two Indian) from the School of Physical Education, Singapore, volunteered to participate in this study. Physical characteristics of the subjects are presented in Tables 1 and 2.

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**Table 1. Physical characteristics of men subjects ($n = 16$)**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>23.6(3.4) 21–35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>173.6(6.9) 157–183</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>62.6(7.5) 49–73.5</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>11.9(4.1) 7–22</td>
</tr>
</tbody>
</table>

Values are mean(s.d.) range. Body fat assessed according to Durnin and Womersley (1974)\(^9\).

**Table 2. Physical characteristics of women subjects ($n = 4$)**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>20.5(0.6) 20–21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>160.3(3.7) 156–165</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>53.5(4.2) 49–58</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>20(2.9) 16–23</td>
</tr>
</tbody>
</table>

Values are mean(s.d.) range. Body fat assessed according to Durnin and Womersley (1974)\(^9\).
Procedures

All subjects undertook a familiarization protocol for laboratory treadmill running (Quinton model 18–60, Getz Corp., Singapore 0511) and outdoor 20-m shuttle running on a flat, unshaded plexipave surface. After familiarization the subjects performed two maximal laboratory tests using the Taylor protocol\(^1\) and two 20-MST\(^2\). All testing was administered randomly over a 4-week period between 09:00 hours and 11:00 hours, with at least 3 days between each test for each subject.

Heart rates were recorded throughout testing using short range telemetry (Sport Tester PE-3000, BMEC, Singapore) heart rate monitors. A metabolic measurement cart (SensorMedics 2900, General Scientific, Singapore) provided analysis of respiratory gases to determine \(\dot{V}O_{2\text{max}}\). A portable cassette player (National: model WA-190N) with an audio cassette (Ramsbottom et al.\(^3\)) set the running pace for the 20-MST. Standard calibration procedures were followed immediately pretesting on the metabolic measurement cart and the cassette player.

Temperature and humidity levels were recorded with the aid of a whirling hygrometer (Brannan model, Hai-Ou Co., Singapore) during all data collection periods.

Physical characteristics were recorded at the first data collection session for each subject, with the exception of body fat and body weight. The percentage body fat was determined by a state registered nurse from the Singapore Sports Council Research Centre, using the estimation methods of Durnin and Womersley\(^4\). Body weight was recorded on each test day and no significant differences were found.

Temperature and percentage relative humidity ranges were recorded during indoor treadmill running and outdoor shuttle running. These are presented in Table 3.

Results

Statistical analyses were carried out using SYSTAT (Evanston, Illinois, USA). Pearson product moment correlations confirmed test-retest reliability for both direct measurement of and predicted \(\dot{V}O_{2\text{max}}\) \((n = 20)\), with \(r\)-values of 0.90 and 0.91, respectively. A \(t\) test for correlated data was employed and indicated significant differences between directly measured and predicted values of \(\dot{V}O_{2\text{max}}\) \((P < 0.01, r = 0.86)\). The direct (test one) and predicted (test one) values of \(\dot{V}O_{2\text{max}}\) are summarized and presented in Table 4.

No differences were found between the maximal heart rate responses of the subjects during the laboratory direct determination of \(\dot{V}O_{2\text{max}}\) and those during the 20-MST. These results are summarized in Table 5.

Discussion

The population in this pilot study provides information on the aerobic fitness of some Singaporean physical education students \((n = 20; 16 \text{ men}, 4 \text{ women})\) which may be useful on a comparative basis.

Aerobic fitness of Singaporean PE students: J. Sproule et al.

| Table 3. Temperature and relative humidity ranges |
|-----------------------------|---------------------|
| Temperature (°C)            | Relative humidity (%) |
| Dry bulb                   | Wet bulb            |
| Indoor (treadmill)          | 23–24               | 17.5–18               | 56–58               |
| Outdoor (20-MST)            | 30–32.5             | 25–26.5              | 62–70                |

| Table 4. Direct and predicted values of \(\dot{V}O_{2\text{max}}\) |
|-----------------------------|---------------------|
| \(\dot{V}O_{2\text{max}}\) (ml kg \(^{-1}\) min \(^{-1}\))    |
| Direct                     | 51.5(6.04)          |
| Predicted                  | 49.1(6.55)          |

Values are mean(s.d.) range; \(t = 3.13, P < 0.01\)

| Table 5. Maximal heart rate (beats min \(^{-1}\)) |
|-----------------------------|---------------------|
| Treadmill                   | 191(10) 173–206     |
| 20-MST                      | 194(8) 181–205      |

Values are mean(s.d.) range; \(t = 1.47, \text{not significant}\)

Singapore is a multiracial society and this was reflected in the different ethnic origins of our subjects (15 Chinese, three Malay and two Indian).

It was interesting to find that 75% of the subjects had a lower than predicted \(\dot{V}O_{2\text{max}}\) compared with their directly determined \(\dot{V}O_{2\text{max}}\). When the predicted \(\dot{V}O_{2\text{max}}\) is based on performance in the 20-MST using the results reported by Ramsbottom et al.\(^3\).

Mahoney\(^11\) suggests that the 20-MST provides a valid and reliable field test of cardiorespiratory fitness for large-scale testing of 12-year-old mixed race populations in the UK \((r = 0.83, \text{boys}; r = 0.76, \text{girls}; P < 0.03)\). The norm tables used in Mahoney's study\(^11\) were originally devised by Leger and Lambert\(^1\) and modified according to Eurofit\(^12\).

The findings of this present study suggest that the norm tables\(^5\) may need to be modified for the active adult Singaporean population, if they are performing the 20-MST in Singapore. There is no apparent specific reason for the lower predicted 20-MST aerobic fitness results. The different racial backgrounds of the subjects may have influenced the results. Also, it is well documented that during exercise in the heat the combined circulatory demands of muscle and skin can impair oxygen transport capacity to the working muscles and may adversely affect performance\(^13\), \(^14\).

References

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