A Maximal Multistage 20-m Shuttle Run Test to Predict \( \dot{V}O_2 \) max*

Luc A. Léger\(^1\) and J. Lambert\(^2\)

\(^1\) Département d'éducation physique, Université de Montréal, CEPSUM, C.P. 6128, Succ. "A", Montréal (Québec), Canada, H3C 3J7
\(^2\) Département de Médecine sociale et préventive, Université de Montréal, Canada

Summary. In order to validate a maximal multistage 20-m shuttle run test for the prediction of \( \dot{V}O_2 \) max, 91 adults (32 females and 59 males, aged 27.3 ± 9.2 and 24.8 ± 5.5 year respectively and with mean \( \dot{V}O_2 \) max (± SD) of 39.3 ± 8.3 and 51.6 ± 7.8 ml · kg\(^{-1}\) · min\(^{-1}\) respectively) performed the test and had \( \dot{V}O_2 \) max estimated by the retroextrapolation method (extrapolation to time zero of recovery of the exponential least squares regression of the first four 20-s recovery \( \dot{V}O_2 \) values). Starting at 8 km · h\(^{-1}\) and increasing by 0.5 km · h\(^{-1}\) every 2 min, the 20-m shuttle run test enabled prediction of the \( \dot{V}O_2 \) max \((y, \text{ml · kg}^{-1} \cdot \text{min}^{-1})\) from the maximal speed \((x, \text{km} \cdot \text{h}^{-1})\) by means of the following regression equation: 

\[
y = 5.857x - 19.458; \quad r = 0.84 \quad \text{and} \quad \text{SEE} = 5.4.
\]

Later, the multistage protocol was slightly modified to its final version, in which the test started at stage 7 Met and continued with a 1 Met (3.5 ml \(O_2\) · kg\(^{-1}\) · min\(^{-1}\)) increment every 2 min. Twenty-five of the 91 subjects performed the 20-m shuttle test twice, once on a hard, low-friction surface (vinyl-asbestos tiles) and another time on a rubber floor, as well as a walking maximal multistage test on an inclined treadmill. There was no difference between the means of these tests or between the slopes of the \(\dot{V}O_2\)max — maximal speed regressions for the two types of surfaces. The 20-m shuttle run test and another maximal multistage field test involving continuous track running gave comparable results \((r = 0.92, \text{SEE} = 2.6 \text{ ml} \ O_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}, n = 70)\). Finally, test and retest of the 20-m shuttle run test also yielded comparable results \((r = 0.975, \text{SEE} = 2.0 \text{ ml} \ O_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}, n = 50)\). It is concluded that the 20-m shuttle run test is a valid and reliable test for the prediction of the \(\dot{V}O_2\) max of male and female adults, individually or in groups, on most gymnasium surfaces.

Key words: \(\dot{V}O_2\) max — Retroextrapolation method — Validity — Reproducibility — Field test

* Supported by the Ministère du Loisir, de la Chasse et de la Pêche du Québec (H.C.S.R. 7919)
Introduction

In order to assess the maximal aerobic power of large groups of subjects, one has to rely on valid, reliable, safe and inexpensive tests. Prediction of VO$_2$ max from the submaximal heart rate response has been repeatedly criticized for its lack of accuracy, particularly on an individual basis (Davies 1968; Rowell et al. 1964; Taylor et al. 1963; Wyndham 1967). One of the most often used tests is the 12-min run (Cooper 1968). This test is, however, maximal from the beginning to the end of the 12-min period, which is contrary to the current tendency to use multistage exercise tests with adults (ACSM 1975). The 12-min run test also depends on the anaerobic capacity, the motivation and the ability to run at an even pace throughout the test. A maximal multistage running track test (Léger and Boucher 1980) for group testing was found to be as valid and reliable as individual indirect maximal multistage treadmill tests, but could not be performed inside gymnasiums because of the high speeds achieved in the final stages of the test. The present study reports a maximal multistage 20-m shuttle run test that was found to be valid and reliable for testing groups of adults on two types of surfaces covering a wide range of hardness and friction.

Methods

Experimental Protocol of the 20-m Shuttle Run Test

A pilot study on five young adults running back and forth on a 20-m course for 5 min at various speeds from 7–14 km · h$^{-1}$ revealed that the energy cost increased by 1 Met (3.5 ml · kg$^{-1}$ · min$^{-1}$) for each 0.5 km · h$^{-1}$. Thus the experimental protocol for the validation studies started at 8 km · h$^{-1}$ and increased by 0.5 km · h$^{-1}$ every 2 min. Once the validation studies were completed, the experimental protocol was slightly modified in order to have a stage increment of 1 Met, to yield the final version of the test which starts at 7.5 km · h$^{-1}$ (Table 2). The final version was used for the reproducibility study. The pace was set with audio signals emitted at specific frequencies using a pre-recorded tape. Subjects were instructed to complete as many stages as possible. Time was announced every 1/2-min of the 2-min stage to help the subject to decide whether or not he should attempt to complete it. The test stopped when the subject was unable to follow the pace (i.e., 3 m behind the 20-m line at the audio signal) or felt that he could not complete the stage.

Oxygen Uptake Measurement

Maximal oxygen uptake was assessed by establishing the O$_2$ recovery curve following the maximal multistage test. The Douglas bag method was used for the collection of four consecutive 20-s samples of expired air immediately at the end of the test. A single exponential regression curve was fitted to the four points with the least-squares regression technique, and VO$_2$ at time zero of recovery (VO$_2$ max in this case) was obtained by retroextrapolating the O$_2$ recovery curve. The retroextrapolation method has previously been found valid ($r = 0.92$) and accurate (SEE = 3.21 ml O$_2$ · kg$^{-1}$ · min$^{-1}$) for the determination of VO$_2$ max after maximal multistage test (Léger et al. 1980). O$_2$ and CO$_2$ were analyzed with Beckman OM-11 and LB-1 analysers previously calibrated with gases of known concentrations (micro-Scholander technique). Attention was paid to starting and ending the 20-s collection period at the same phase of the respiratory cycle and to timing this period exactly.