A MULTI-STAGE SHUTTLE RUN AS A PREDICTOR OF RUNNING PERFORMANCE AND MAXIMAL OXYGEN UPTAKE IN ADULTS

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ABSTRACT

The aim of this study was to assess the validity of a 20 metre multi-stage shuttle run (20-MST) as both a field test of cardio-respiratory endurance and as a predictor of competitive performance in a 10 kilometre (10 km) race. Nine male subjects (age 35.4 ± 5.8 years) (mean ± SD) underwent a laboratory test of maximum oxygen uptake on a treadmill (VO₂ max 59.0 ± 9.9 ml.kg⁻¹. min⁻¹), completed the 20-MST (score 105 ± 23.7 laps/11.4 ± 2.7 paliers) and competed in a 10 km race (finishing time 41.8 ± 7.3 minutes). Analysis using Pearson’s Product Moment Coefficient revealed high correlations between these variables (20-MST vs. VO₂ max, r = 0.93; 20-MST vs. 10 km, r = −0.93; VO₂ max vs. 10 km, r = −0.95). These results confirm that the 20-MST is a valid field test of cardio-respiratory endurance and suggest that it can additionally be used to predict relative running performance over 10 km.

Key words: 20-MST, VO₂ max, 10 km race, Validity, Correlation, Endurance

INTRODUCTION

It is widely recognised that maximum oxygen uptake (VO₂ max) is one of the main determinants of performance in endurance-based sports, although other factors may also contribute significantly (Lehmann et al, 1983; Sjödin and Svedenhag, 1985). However, due to the complexities of measuring oxygen consumption in the laboratory, methods which attempt to predict VO₂ max without the expense, time and expertise required in such a procedure are very attractive. One such test, the 20 metre multi-stage shuttle run (20-MST; Léger et al, 1984) requires little equipment (principally a tape recorder) and is suitable for mass testing. This test, which is normally administered indoors, is progressive in nature and utilises a pre-recorded sound signal to dictate running speed. Thus the problems associated with self-pacing encountered in other running tests, for example the mile run (Watkins and Ewing, 1983) and 12-minute run (Johnson et al, 1979) are, to a large extent, overcome.

Results from laboratory measures or field tests are often used to predict potential performance in endurance events (Costill, 1986; Hagan et al, 1981). It may be of interest to many sportsmen and coaches, therefore, to examine the relationship between the 20-MST and competitive performance. So far no studies have been published relating to this topic.

This study was carried out to compare three different measures of endurance (VO₂ max, 20-MST, and race time over 10 kilometres [10 km]) with the aim of assessing the validity of the 20-MST as both a field test of cardio-respiratory capacity, and as a predictor of competitive performance in an endurance event.

MATERIALS AND METHODS

Nine adult male subjects took part in this study. All participated in sport and several were in training for competitive endurance events. All tests were administered by the same researcher in late afternoon or early evening.

The first test was the 20-MST, followed two days later by the 10 km run, the latter being a competitive race. Subjects then reported back to the laboratory within two weeks for the assessment of VO₂ max.

The 20-MST was administered in a sports hall using the original protocol (Léger and Lambert, 1982) but utilising a different scoring system developed by the Human Performance Laboratory at The Queen’s University of Belfast. The 20-MST involves running between two lines set 20 metres apart at a pace dictated by a cassette recording emitting tones at appropriate intervals. Velocity is set at 8.5 km.hr⁻¹ for the first minute, increasing by 0.5 km.hr⁻¹ every minute thereafter. The test score achieved by the subject is the number of 20 metre laps completed before the subject either withdraws voluntarily from the test, or fails to be within 3 metres of the end lines on two consecutive tones. Scoring by laps differs from the “paliers” (stages or minutes) used in the original version of the test (Léger and Lambert, 1982).

The 10 km time used in this study was established in a competitive race of that distance, two days after the 20-MST. No subjects reported any residual feelings of fatigue following the initial test.

VO₂ max was assessed during uphill treadmill running using an on-line gas analyser (Mijnhardt B.V., Holland). The instrument was calibrated before each test, using gases of known and guaranteed concentrations. Following familiarisation with procedures and a short (3 minute) warm-up the treadmill was set at a velocity slightly less than the subject’s average speed for his 10 km run. Thereafter the gradient was increased by 2% every minute until volitional exhaustion. The objective criteria used in assessing whether or not the subject had reached VO₂ max were as described by Shephard (1984), i.e., a plateau of oxygen consumption being reached despite an increase in work load, a heart rate within 10% of predicted maximum, and a respiratory exchange ratio greater than 1.0.

During the laboratory visit, body composition was also assessed using the sum of four skinfolds (Durnin and Rahaman, 1967).

RESULTS

Results are expressed as group mean ± standard deviation. Correlations are by Pearson’s Product Moment Coefficient (r). The physical characteristics for the sample are given in Table I.
shown in Table II. Both tables illustrate well the heterogeneous nature of the sample population. For the purpose of comparison with other studies, the number of "Paliers" has been calculated from the lap scores on the 20-MST and included in Table II. Figures 1-3 display the relationships between all endurance measures using linear regression by the least squares method. Table III shows the obtained correlations.

\[
y = 18 + 0.39x \\
\text{VO}_2 \text{ max (ml.kg}^{-1}\text{min}^{-1})
\]

\[r = 0.93 \text{ S.E.E.} = 3.91\]

![Fig. 1: The relationship between VO2 max and 20-MST. Each point represents individual values. Regression equation, Pearson's 'r', and standard error of estimate (S.E.E.) are shown.](image)

\[
y = 112.7 - 1.29x \\
\text{VO}_2 \text{ max (ml.kg}^{-1}\text{min}^{-1})
\]

\[r = -0.95 \text{ S.E.E.} = 3.32\]

![Fig. 2: The relationship between VO2 and 10 km race performance. Each point represents individual values. Regression equation, Pearson's 'r', and standard error of estimate (S.E.E.) are shown.](image)

\[
y = 71.9 - 0.29x \\
\text{10km time (mins)}
\]

\[r = -0.93 \text{ S.E.E.} = 2.89\]

![Fig. 3: The relationship between 10 km race performance and 20-MST. Each point represents individual values. Regression equation, Pearson's 'r', and standard error of estimate (S.E.E.) are shown.](image)

### DISCUSSION

In general the endurance performance for the sample group was similar to that found in other studies. Mean VO2 max for the test group (59 ml.kg. \(^{-1}\)min\(^{-1}\)) would be considered high relative to untrained groups (approximately 45

ml.kg. \(^{-1}\)min\(^{-1}\); Åstrand and Rodahl, 1977), but slightly less than the recreational distance runners reported by Cavanagh and Williams (1982), who showed a mean VO2 max of 64.7 ml.kg. \(^{-1}\)min\(^{-1}\).

Although few studies have been carried out with adults using the 20-MST, a mean score of approximately 10 paliers has been calculated from the data in the study by Léger and Lambert (1982). The mean score in the current study (105 laps = 11.4 paliers) is also greater than the mean score of 17 year old boys (9.3 paliers) studied by Léger and co-workers (Léger et al, 1984). Thus the performance of the group in the present study would be rated high relative to a normal population but slightly below that of endurance athletes in regular training.

The coefficient of correlation between the 20-MST and VO2 max was higher than that reported elsewhere, although much of the published data concerning the 20-MST refers to children. Van Mechelen and co-workers report a correlation coefficient of \(r = 0.76\) between VO2 max and 20-MST for 82 boys and girls aged between 12 and 14 years (Van Mechelen et al, 1986). However, a correlation of \(r = 0.91\) has been reported between VO2 max and 20-MST in adults (Léger and Lambert, 1982). This result is only slightly less than the correlation found in the current study (\(r = 0.93\)). These results suggest that the 20-MST is a valid indicator of maximal aerobic power in various populations and may be used to estimate VO2 max with reasonable accuracy (Fig. 1).

The correlation coefficient of \(r = -0.95\) between VO2 max and 10 km race performance (Fig. 2) shown in this study is higher than that found by Sjödin and Svedenhag (1985; \(r = -0.78\)), who used a sample of runners examined over the marathon distance. However, their sample consisted of trained marathon runners, implying a relative homogeneity which may have affected the outcome of the correlations. This is substantiated by the relatively narrow range of VO2

### Table I

| Subject characteristics (n = 9, mean ± SD and range) |
|---|---|---|---|
| Age (yr) | Height (cm) | Weight (kg) | % Fat |
| 35.4 ± 5.8 | 177.4 ± 5.65 | 74.4 ± 6.4 | 12.4 ± 6.4 |
| (26-47) | (170-179) | (56-92) | (7.2-20.7) |

### Table II

| Performance results (n = 9, mean ± SD and range) |
|---|---|---|---|
| VO2 max (ml.kg. \(^{-1}\)min\(^{-1}\)) | 20-MST (laps) | 20-MST (paliers) | 10 km Race (mins) |
| 59.0 ± 9.9 | 105 ± 23.7 | 11.4 ± 2.7 | 41.8 ± 10.4 |
| (43-75) | (64-135) | (7.5-14) | (33-52.5) |

### Table III

| Pearson Product Moment Correlation Coefficients relating maximum oxygen uptake, multi-stage shuttle run and 10 km race time (n = 9, all P < 0.01) |
|---|---|---|
| VO2 max | 20-MST | 10 km Race |
| VO2 max | x | 0.93 | -0.95 |
| 20-MST | x | -0.93 | |

Figures 1-3 illustrate well the relationships between all endurance measures using linear regression by the least squares method. Table III shows the obtained correlations.
max reported for the runners of that study. Kumagai and co-workers reported an even lower correlation \( r = -0.67 \) between \( \text{VO}_2 \) max and 10 km performance in their study of 17 endurance athletes aged between 16-18 (Kumagai et al, 1982). This low correlation may also be due to the heterogeneous nature of the group, a feature pointed out by van Mechelen et al (1986). For these reasons direct comparison between studies of this nature may be difficult, due to variation in the choice of sample population.

The 20-MST correlates highly with race time over 10 km \( r = -0.93 \). The authors are unaware of any other studies in this area but, even within the constraints of the sample size used in this study, it appears that the 20-MST could be used as an accurate predictor of race performance (Fig. 3). However, more work with larger samples would be required to confirm these findings.

The high correlation coefficients obtained in this study can be explained by several factors. The heterogeneous nature of the sample meant that individual variances in performance between tests did not greatly affect the final correlations. Also, whilst inter-subject variability in terms of performance was large, all subjects were involved in endurance-based sports, and familiar with high levels of physical exertion. This factor probably resulted in reduced intra-subject variability between tests, compared with relatively sedentary individuals. Finally, the 20-MST is an appropriate field test of aerobic endurance for the following reasons:

1. The requirement for pace judgement is eliminated by the use of a pre-recorded audio signal, (2) The incremental nature of the test ensures a gradual rise in workload and therefore heart rate, (3) The test appears to be highly reliable \( r = 0.975 \); Léger and Lambert, 1982) and (4) Large numbers can be tested simultaneously, although some caution should be taken when testing groups or individuals whose fitness levels are unknown, due to the maximal nature of the test.

CONCLUSION

The high correlation shown in this study, whilst undoubtedly influenced by the heterogeneous nature of the sample and the willingness of the group to perform maximally, does show that the 20-MST is a valid estimator of maximum oxygen consumption and race performance over 10 km. Additionally, \( \text{VO}_2 \) max is once again shown to be a factor of great importance in determining aerobic performance.

References


BOOK REVIEW

Title: DRUG USE AND DETECTION IN AMATEUR SPORTS
Author: Mauro G. Di Pasquale, MD
Publisher: M. G. D. Press, Ontario. UK Agent: Quest Meridien, Beckenham 1984
Price: £16.50 + P & P £1.50 123 pages Figs & Tables Index

The author was himself a world class powerlifter and is a doctor of medicine. He explains the classification of banned drugs and the methods of drug control for all involved in sport. Such is the pace of doping control that the current list of banned substances has additions not covered in the book. The book is written with the North American market in mind and many of the drugs mentioned are not used in Great Britain.

Although the first third of the book is of interest to most readers the rest is devoted to the metabolic pathways of such drugs as anabolic steroids, growth hormone and other miscellaneous compounds. It cannot be recommended as a book for technical information on British drug enforcement rules.

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