An Indirect Continuous Running Multistage Field Test: The Université de Montréal Track Test*

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LÉGER Luc and BOUCHER, Robert. An indirect continuous unning multistage field test. **Can. J. Appl. Spt. Sci.** *5:2 77-84, 1980. The object of this study was to report on the validity and reliability of the Université de Montréal Track Test (UM-TT). The UM-TT is a continuous maximal indirect multistage running field test based on the energy cost of running. The first stage is set at a walking speed that requires 5 Mets; thereafter the speed is increased by 1 Met every two minutes. In order to assess the validity of the UM-TT, 25 subjects, 24.4 ± 2.8 years old ($\overline{X}$ ± SD) had their $\dot{V}O_2max$ predicted with the UM-TT and measured directly with a running multistage treadmill test. Averages (± SD) were not significantly different (61.5 ± 10.6 and 61.4 ± 10.9 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$, respectively), other statistics being $r = 0.96$, $\Delta = 0.09 \pm 2.90$ ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ and $S_{yx} = 2.81$ ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. Seven males, 20.6 ± 1.0 years old, had also their $\dot{V}O_2max$ measured directly during the UM-TT. Comparison of predicted and directly measured $\dot{V}O_2max$ yielded similar results: 70.0 ± 4.5 and 70.7 ± 6.0 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$, respectively with $r = 0.66$, $\Delta = 0.67 \pm 4.53$ and $S_{yx} = 3.71$. Reliability of the UM-TT was assessed by repeating the test twice on 60 subjects (49 males and 11 females; 39 subjects below 30 years old and 21, above; and 30 subjects below and above 15 Mets). Results were as follows: $\overline{X}$ ± SD = 54.1 ± 8.2 and 54.2 ± 8.5, $r = 0.97$, Δ 0.11 ± 1.92, and $S_{yx} = 1.92$. Similar reliability trends were observed for each one of the subgroups of subjects. It is concluded that the UM-TT is valid and reliable to estimate the $\dot{V}O_2max$ of trained and untrained young and middle-age males and females.*

$\dot{V}O_2max$, maximal tests, field tests

Cette étude avait pour but de vérifier la validité et la fidélité du test de piste de l'Université de Montréal (TP-UM). Le TP-UM est un test de plancher maximal, indirect, continu et à paliers multiples où la vitesse initiale de 5 Mets est augmentée de 1 Met à toutes les 2 minutes selon les courbes du coût énergétique de la course publiées dans la littérature. Les sujets, 25 hommes âgés de 24.4 ± 2.8 ans (moyenne et écart type), obtinrent des résultats semblables lorsque le $\dot{V}O_2max$ était prédit par le TP-UM (61.5 ± 10.6 ml·kg⁻¹·mn⁻¹) ou mesuré directement lors d'un test de course progressif sur tapis roulant (61.4 ± 10.9). Les autres statistiques observées étaient les suivantes: $r = 0.96$, $\Delta = 0.094 \pm 2.90$ ml $O_2 \cdot kg^{-1} \cdot mn^{-1}$ et $S_{yx} = 2.81$ ml $O_2 \cdot kg^{-1} \cdot mn^{-1}$. Sept hommes, âgés de 20.6 ± 1.0 ans furent aussi évalués directement lors du TP-UM. La mesure prédite et la mesure directe étaient semblables (70.0 ± 4.5 et 70.7 ± 6.0, respectivement) avec $r = 0.66$, $\Delta = 0.67 \pm 4.53$ et $S_{yx} = 3.71$. Afin de vérifier la fidélité du TP-UM, 60 sujets (49 hommes et 11 femmes, 39 sujets âgés de 20 à 30 ans et 21, de 31 à 40, et 30 sujets en haut et en bas de 15 Mets) répétèrent le test à 2 occasions. Les résultats furent les suivants: $\overline{X}$ ± E.T. = 54.1 ± 8.2 et 54.2 ± 8.5 ml $O_2 \cdot kg^{-1} \cdot mn^{-1}$, $r = 0.97$, $\Delta = 0.11 \pm 1.92$ et $S_{yx} = 1.92$. Les mêmes tendances de fidélité furent observées pour chacun des sous-groupes de sujets. Le TP-UM apparaît donc valide et fidèle pour estimer le $\dot{V}O_2max$ des adultes jeunes et d'âge moyen des deux sexes, entraînés ou non.

Flat running is one of the most commonly used exercises for aerobic training. As the increase in $\dot{V}O_2max$ with training is specific to the type of activity used both for training and testing (Bouchard, **et al.** 1979; Léger, **et al.** 1979; McArdle **et al.** 1978) a running test appears to be best suited for the measurement of the VO_2max of runners or joggers. For these reasons and others, such as simplicity, financial cost, etc., mass field tests are very popular. The 12-min run (Cooper, 1968) is probably the most widely used of these tests. Although this test is valid and reliable (Cooper, 1968; Martin, 1971; Wyndham **et al.** 1971) it also depends on the subject's motivation as well as his anaerobic capacity to an unknown extent. Furthermore, the 12-min test is a maximal all-out effort with considerable stress; progressive tests appear somewhat safer (A.C.S.M., 1975).

A continuous running multistage field test was constructed as an alternative to the all-out 12-minute test. The test, the Université de Montréal Track Test, has been administered to more than 3,000 adults enrolled in physical fitness classes at the Université de Montréal during the last three years. The purpose of this article is to present reliability and validity data on this test. More specifically, $\dot{V}O_2max$ predicted with the UM-Track Test was compared to $\dot{V}O_2max$ measured directly on the treadmill using the same protocol (i.e. horizontal running); comparison was also made with a standard Balke test (i.e. inclined walking). In a second set of experiments, the comparison was made with an inclined running test often performed by athletes. Next step was to assess the $\dot{V}O_2max$ directly on the track. Test and retest were also performed by different groups of subjects to assess the reliability of the test. Finally, the UM-Track Test was compared to other popular field tests.

METHODOLOGY

The Université de Montréal Track Test (UM-Track Test) is a continuous, indirect and maximal multistage track test based on the energy cost of walking (Jankowski **et al.** 1973) and running (Shephard, 1969). Shephard's equation for the energy cost of horizontal treadmill running was chosen because of its median position among other reported curves (Curve 1, Figure 1). Shephard's equation (Curve 1, Figure 2),

$$y = 2.98x + 7.6$$

where y is the gross energy cost of running in $ml \cdot O_2 \cdot kg^{-1} \cdot min^{-1}$ and x is the speed of running in $km \cdot h^{-1}$, had to be modified for the track running test. The energy cost was increased by 3% for the slow runners (i.e. maximal aerobic speed = 10 $km \cdot h^{-1}$) and decreased by 3% for the fast runners (i.e. 20 $km \cdot h^{-1}$) since these runners probably represent the less and the more efficient ones respectively (Bransford and Howley, 1977) and since Margaria **et al.** (1963) reported a ± 3% variation in the energy cost of running. The resulting equation (Curve 2, Figure 2),

$$y = 2.667x + 11.838$$

was also corrected for the wind resistance effect. This was done with Pugh's equation (Pugh, 1970) for the energy cost of running against air,

$$y = 0.00418\ Ap\ x^2$$

where y is the energy cost of air resistance in $l\ O_2 \cdot min^{-1}$, Ap, the projected area in m^2 (= 0.266 x surface area, Pugh, 1970) and x, the speed of the wind in $m \cdot sec^{-1}$. The calculated energy cost of air resistance of Pugh's subjects (average weight 61.3 kg) was added to the energy cost of horizontal treadmill running (equation 2) which yielded the following equation (Curve 3, Figure 2),

$$y = 0.0324x^2 + 2.143x + 14.49$$

for the gross energy cost of track running. Equation 4 was used to construct the UM-Track Test protocol (Table 1).

The UM-Track Test was conducted on a 166.7 m indoor track with inclined curves. Red pylons were placed at every quarter section of the track. The subjects were paced with sound signals emitted at specific frequencies using a prerecorded tape. As shown in Table 1, the speed of the multistage is initially set at 5 Mets (i.e. 6.00 $km \cdot h^{-1}$); thereafter, the speed is increased by 1 Met by stages of 2-minute duration. Subjects were instructed to complete as many stages as possible. Time was announced every half-minute of the two-minute stage to help the subject to decide whether or not he should attempt to complete it. Test stopped when the subject was at least 30 feet behind the appropriate red pylon at the sound signal or felt that he could not complete the stage.

Five series of experiments were done to check the validity and the reliability of the UM-Track Test.

Experiment 1. The predicted $\dot{V}O_2max$ of the UM-Track Test was compared to the $\dot{V}O_2max$ measured directly with the UM-Track Test done on the treadmill and with a modified Balke test. The modified Balke test started at 0% grade with a speed of 4.8 km/h (3 mph) and the slope was increased by 2.5% every two minutes up to 20% where it remained at this level while the speed was increased by 0.4 km/h (0.25 mph) every two minutes. The subjects, 6 untrained and 9 trained males were 35.2 ± 3.7 and 22.0 ± 3.8 (X ± SD) years old respectively. Heart rate was recorded during the last 15 s of each stage both for the track (telemetry) and the treadmill tests. $\dot{V}O_2$ for the treadmill tests was analyzed by the open circuit technique. O_2 and CO_2 were analyzed with an infrared CO_2 analyzer and a paramagnetic O_2 analyzer, frequently calibrated against gases of known concentration (micro-Schollander technique). Expired air was collected every minute in meteorological balloons. Air volume was measured with a Tissot gasometer.

Experiment 2. In order to see if inclined and horizontal running yielded the same $\dot{V}O_2max$, ten additional subjects, including 1 female, 20 ± 1.4 years old performed the UM-Track Test and a running inclined test where the treadmill was initially set at 11.3 km/h (7 mph), 0% grade and the slope was increased by 2.5% every two minutes up to 12.5% after which the speed was increased by 1.6 km/h (1 mph) every two minutes.

Experiment 3. Seven males, aged 20.6 ± 0.98 years old, performed the UM Track Test and the predicted $\dot{V}O_2max$ was compared with the $\dot{V}O_2max$ measured by the backward extrapolation method using the O_2 recovery curve (Léger et al., 1980).

Experiment 4. Sixty adults, including 11 females, 19 to 40 years old performed the UM-Track Test twice within a 10-day period and with at least two days rest in between. Tests and retests were done in groups of 5-10 subjects simultaneously.

Experiment 5. Twenty five physical education students, males and females, performed the following tests at the rate of one test a week in this order: the UM-Track Test, the Astrand-Ryhming bicycle test (Astrand and Ryhming, 1954), the Canadian Home Fitness Test as modified by Jetté **et al.** (1976) and the 12-min run test (Cooper, 1968).

RESULTS

Experiment 1. The first set of experiments indicated that predicted $\dot{V}O_2max$ by the UM-Track Test and the direct measurement of $\dot{V}O_2max$ with the UM protocol done on the treadmill were similar with values of 44.9 ± 4.5 and 44.4 ± 5.0 $ml \cdot kg^{-1} \cdot min^{-1}$ respectively in untrained subjects. The same was true for trained subjects (64.0 ± 3.5 and 64.7 ± 5.0 $ml \cdot kg^{-1} \cdot min^{-1}$). The Balke protocol yielded higher values (67.6 ± 5.13) than the UM protocol done on the treadmill (paired t test) in trained but not in untrained subjects (42.4 ± 4.2).

Experiment 2. As opposed to the high grade walking Balke test, directly measured $\dot{V}O_2max$ with the inclined running test (12.5%) and predicted $\dot{V}O_2max$ with the UM Track Test were similar (68.0 ± 5.7 and 68.8 ± 4.3 $ml \cdot kg^{-1} \cdot min^{-1}$ respectively). When these results were combined with the ones found in the first set of experiments (N = 25 altogether), directly measured $\dot{V}O_2max$ with running tests done on the treadmill and predicted $\dot{V}O_2max$ with the UM Track Test were similar (61.4 ± 10.9 and 61.5 ± 10.6 $ml \cdot kg^{-1} \cdot min^{-1}$ respectively) with an r of 0.96, a Δ of 0.094 ± 2.90 $ml\ O_2 \cdot kg^{-1} \cdot min^{-1}$ and a S_{yx} of 2.81

ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ (Figure 3) where r is the Pearson's correlation coefficient, Δ the difference between the two scores and S_{yx} the standard error of the estimate.

Experiment 3. $\dot{V}O_2max$ measured with the backward extrapolation method after the UM-Track Test was done on the track and predicted values were similar (70.7 ± 6.0 and 70.0 ± 4.5 ml·kg⁻¹·min⁻¹) with an r of 0.66, a Δ of 0.67 ± 4.53 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ and a S_{yx} of 3.71 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$.

Experiment 4. Predicted $\dot{V}O_2max$ of the UM-Track Test done twice on 60 subjects were similar (15.45 ± 2.33 and 15.48 ± 2.43 mets) with an r of 0.97, a Δ of 0.03 ± 0.55 mets and a S_{yx} of 0.55 mets. Similar results were obtained whether the subjects were above or under 15 mets (Figure 4). When the 60 subjects were divided in two groups whether they were under or above 30 years old, results were again similar for the test and retest in both groups (**22.7 ± 7.1 years old:** N = 39, test 1 = 16.13 ± 2.20 and test 2 = 16.26 ± 2.27 mets, r = 0.97 and **33.8 ± 3.0 years old:** N = 21, test 1 = 14.19 ± 2.06 and test 2 = 14.05 ± 2.06, r = 0.97). Similar trends were also observed for the two sexes (**males:** N = 49, test 1 = 16.06 ± 2.11 and test 2 = 16.12 ± 2.17, r = 0.97 and **females:** N = 11, test 1 = 12.73 ± 0.90 and test 2 = 12.64 ± 1.12, r = 0.88).

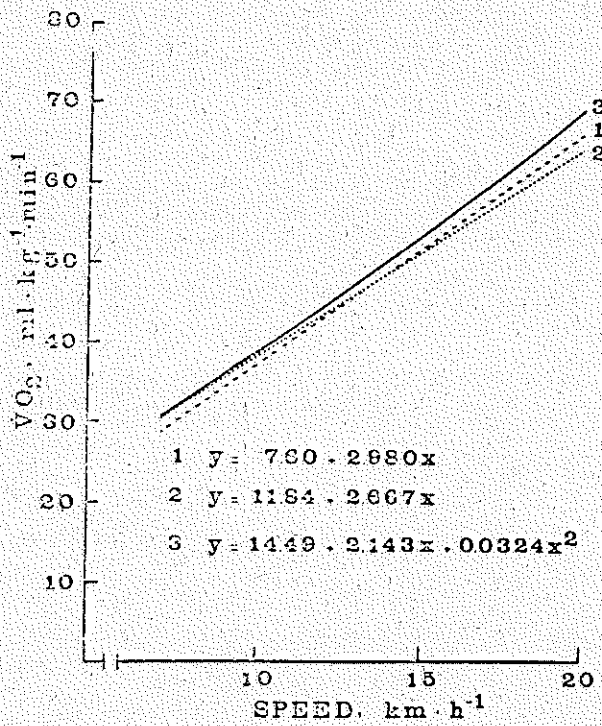

Figure 2. Gross energy cost of track running (Curve 3). The gross energy cost of horizontal treadmill running (Curve 1, Shephard, 1969) was adjusted for the good and the bad runners by adding and subtracting 3% at 10 and 20 km·h⁻¹ respectively (Curve 2) and corrected for the wind resistance (Curve 3) according to Pugh (1970).

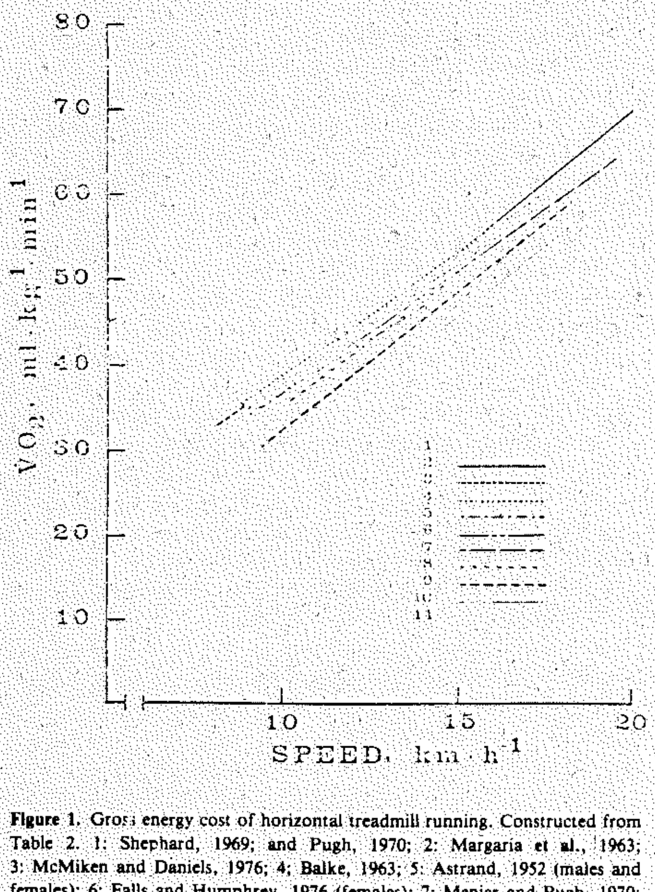

Figure 1. Gross energy cost of horizontal treadmill running. Constructed from Table 2. 1: Shephard, 1969; and Pugh, 1970; 2: Margaria et al., 1963; 3: McMiken and Daniels, 1976; 4: Balke, 1963; 5: Astrand, 1952 (males and females); 6: Falls and Humphrey, 1976 (females); 7: Menier and Pugh, 1970; 8: ACSM, 1975; 9: Mayhew, 1977; 10: Costill et al., 1953 (endurance and marathon runners); 11: Bransford and Howley, 1977 (trained and untrained males and females).

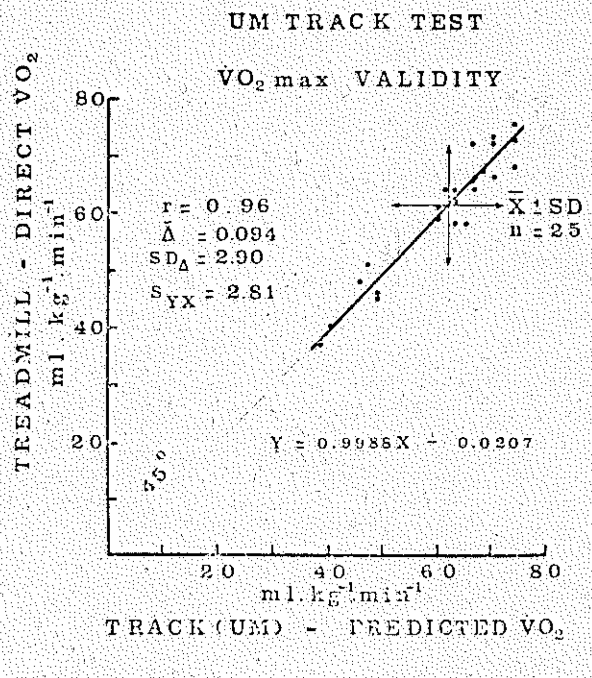

Figure 3. Correlation between predicted $\dot{V}O_2max$ of the UM-Track Test and the $\dot{V}O_2max$ measured directly on the treadmill (inclined or horizontal running).

Experiment 5. In the fifth set of experiments (Figure 5), predicted $\dot{V}O_2max$ was similar for the UM-Track Test, the bicycle Astrand-Ryhming test and the Canadian Home Fitness test, but slightly lower for the 12-min run test (56.7 ± 5.3, 57.1 ± 12.0, 55.4 ± 8.4 and 53.1 ± 8.6 respectively). The difference between the highest and the lowest score of the four tests was 13 ± 6.7 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. Average of the four tests was 55.8 ± 7.1 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. Correlation coefficients with the UM-Track Test were 0.71 (Astrand-Ryhming), 0.40 (CHFT) and 0.84 (12-min run).

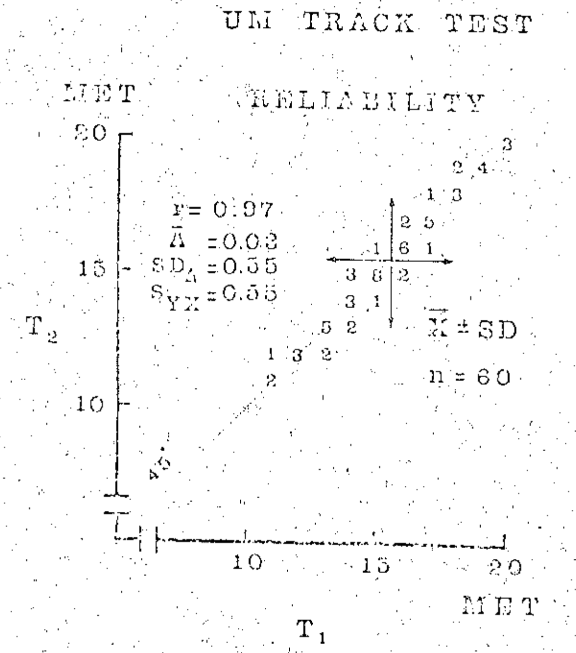

Figure 4. Test-Retest correlation for the UM-Track Test in trained and untrained subjects.

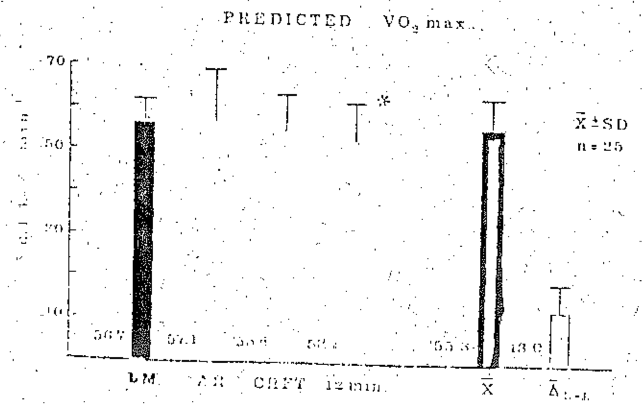

Figure 5. Comparison between the $\dot{V}O_2max$ predicted from the UM-Track Test, the bicycle Astrand-Ryhming test, the Canadian Home Fitness Test and the 12-min run test (*$p < 0.05$).

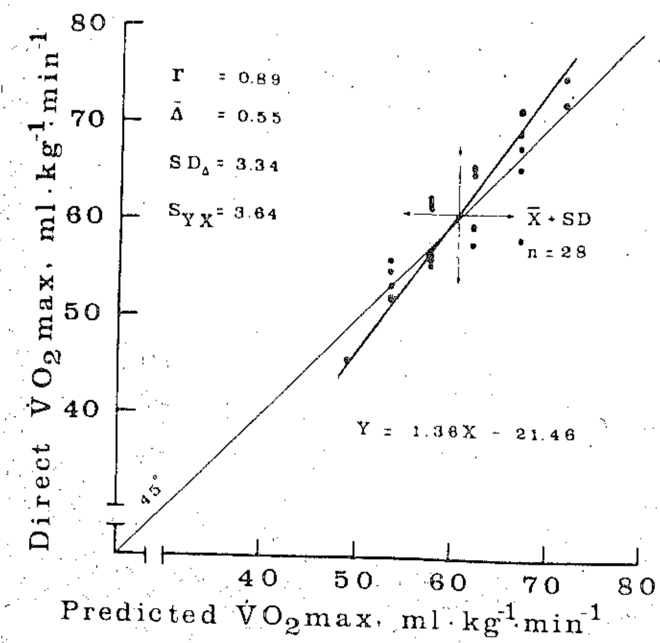

Figure 6. Correlation between the predicted (ACSM, 1975) and the direct $\dot{V}O_2max$ achieved during a maximal multistage running test on an inclined treadmill.

DISCUSSION

Validity of the UM-TT. Prediction of $\dot{V}O_2max$ with maximal indirect multistage tests is based on the energy cost of each stage. Limitation and accuracy of the prediction depend on the inter-individual variation of the energy cost of the test stages. The magnitude of the variations is not the same for all the activities (i.e, running vs. swimming). It is not known if the magnitude of the variation is similar for inclined treadmill running or walking, or horizontal treadmill or track running. With a correlation coefficient of 0.96 and a standard error of the estimate of 2.81 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ (4.5%) between $\dot{V}O_2max$ predicted with the UM-Track Test and $\dot{V}O_2max$ measured directly with a multistage running treadmill test (Figure 3), the inter-individual variability of the UM-Track Test is not large. Similar comparison between predicted and directly measured $\dot{V}O_2max$ using the inclined running treadmill test (Figure 6), indicate slightly large variability ($r = 0.89$ and $S_{yx} = 3.64$ ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ (5.9%), unpublished material). Horizontal running on a track might just be a more familiar form of exercise than inclined treadmill running or walking. This remains to be verified more rigorously however. In any case, present data are satisfactory and consistent with the ones reported in the literature (Table 3).

As stated earlier, assessing the inter-individual variability is very important for a maximal indirect test used to predict $\dot{V}O_2max$. In this regard, the way r and S_{yx} are computed is also very important. For instance, using a regression curve computed from submaximal data to assess $\dot{V}O_2max$ might yield an erroneous estimation. It might be expected that part of the last completed stage of a multistage test has been done in anaerobic state, the true aerobic expense (i.e. $\dot{V}O_2max$) being lower than predicted. As far as it is known, this has never been investigated rigorously. However, there are indications that support this hypothesis. For example, as reported by Bruce **et al.** (1973), the regression equation based on maximal data alone ($y = 3.288x + 4.07$, where y is the predicted $\dot{V}O_2$max and x, the endurance time for the Bruce test) yields lower $\dot{V}O_2$max than the one obtained with the regression equation based on their submaximal data ($y = 2.94x + 8.33$). In addition, the inter-individual variability appears to be larger for maximal data than for submaximal data (Table 3). This is the reason why the statistics of this study (r, Δ, and S_{yx}) were computed on integer or discrete values of the test performance (i.e. . . . 10, 11, 12 Mets or . . . 8, 10, 12 minutes duration). Table 3 indicates that the UM-Track Test not only compared favorably with studies based on continuous data, but also, compared favorably with inclined treadmill running or walking tests based on maximal data alone. As shown in this table, data presented by Froelicher and Lancaster (1974), raised some doubts about the validity of maximal indirect tests to predict $\dot{V}O_2$max but their results could not be confirmed neither by the present study, nor by others (Bruce **et al.**, 1973 and Pollock **et al.**, 1976).

In the present study, r and S_{yx} were computed between the predicted energy cost of the last completed stage and the direct measurement of $\dot{V}O_2$max instead of using time duration of the test as it was done in other studies (Table 3); this does not affect the results as far as the accuracy of the test prediction is concerned. However, the regression equation would have to be used to correct the predicted $\dot{V}O_2$max unless the original equation (i.e. equation 4 for the present study for horizontal running or A.C.S.M. (1975) O_2 cost for inclined treadmill running) is already and sufficiently accurate. This would be the case when the regression equation between the predicted $\dot{V}O_2$max and the directly measured $\dot{V}O_2$max yields a slope close to 1 and Y intercept close to 0. This was true for the UM-Track Test indicating that equation 4 can be used to predict $\dot{V}O_2$max without any correction (Figure 3). Predicted $\dot{V}O_2$max estimates with the A.C.S.M. data (1975) for running treadmill tests were not as accurate however (Figure 6).

When $\dot{V}O_2$ was measured with the backward extrapolation method and compared to the predicted value of the UM-Track Test (Experiment 3), averages were similar but the r was low (0.66). This is not unexpected with a small group (N = 7) of very homogeneous subjects (70.7 ± 6.0 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$).

The validity of a test is not only related to the measure itself but also to the objectives of the evaluation process. In this regard, using the UM-Track Test to prescribe a running training load is advantageous since the same activity is used for both testing and training with the same mechanical efficiency for each individual. As a matter of fact, training loads are currently and satisfactorily prescribed from maximal running speed using the UM-Track Test protocol (Table 1). Flat running cannot as easily be prescribed from an inclined walking or running test whether it is a direct or an indirect test.

Table 1. The University of Montreal Track Test

STAGE[1]	$\dot{V}O_2$	TIME	SPEED	SPLIT TIMES		
				166.7m	200m	1 km
Met	$ml \cdot kg^{-1} \cdot mn^{-1}$	min	$km \cdot h^{-1}$	sec	sec	min
WALK						
5	17.5	2	6.00	100.00	120.00	10:00
7	24.5	4	7.10	84.51	101.41	8:27
RUN						
9	31.5	6	7.16	83.80	100.55	8:22
10	35.0	8	8.48	70.75	84.90	7:04
11	38.5	10	9.76	61.47	73.76	6:08
12	42.0	12	11.00	54.53	65.43	5:27
13	45.5	14	12.21	49.13	58.96	4:54
14	49.0	16	13.39	44.81	53.77	4:29
15	52.5	18	14.54	41.27	49.53	4:07
16	56.0	20	15.66	38.32	45.98	3:50
17	59.5	22	16.75	35.81	42.98	3:55
18	63.0	24	17.83	33.66	40.39	3:22
19	66.5	26	18.88	31.79	38.14	3:10
20	70.0	28	19.91	30.14	36.17	3:01
21	73.5	30	20.91	28.69	34.43	2:52
22	77.0	32	21.91	27.39	32.87	2:44
23	80.5	34	22.88	26.22	31.47	2:37

[1]Stage numbers are given in Met equivalents; for each stage, the gross energy cost ($\dot{V}O_2$), the cumulative time (TIME), the speed or the corresponding split times are also given for testing and training purposes as well.

Table 2. Regression equations for the gross energy cost of horizontal treadmill running.

Reference	n	sex	trained state[1]	m[3]	b[3]
ACSM, 1975	?	?	?	3.0625	5.25
Astrand, 1952	10	F		2.61	10.2
	9	M		2.93	9.33
Balke, 1963	5	M		2.86	10.2
Bransford, 1977	10	F	UT	2.517	10.942
	10	F	T	3.033	3.511
	10	M	UT	3.40	− 0.510
	10	M	T	3.383	− 3.562
Costill, 1973	16	M	T[2]	4.20	− 15.54
	6	M	T[2]	3.4	− 5.24
Falls, 1976	7	F	U	2.92	8.66
Margaria, 1963	2	M	T	3.33	3.5
Mayhew, 1977	9	M	T	3.318	− 0.82
McMiken, 1976	8	M	T	2.867	5.363
Menier, 1970	4	M	T	2.95	7.0
Pugh, 1970	4	M	T	2.979	7.545
Shephard, 1969	14	M	U	2.98	7.6

[1]UT & T: Untrained and trained
[2]Endurance runners (n = 16) and marathon runners (n = 6)
[3]$y = mx + b$ where $y = \dot{V}O_2$, ml·min^{-1} and x = speed, km·h^{-1}

Prescription based on heart rate response might also lack some accuracy since maximal heart rate is not necessarily the same on the track and on the treadmill where different ambient conditions might prevail. For example, maximal heart rates of the 9 trained subjects of the first set of experiments were 201.1 ± 7.2, 198.4 ± 5.9, 192.3 ± 5.4 and 193.4 ± 6.9 for the UM-Track Test, first and second trial on the track, third trial on the treadmill and the Balke test respectively. The track maximal heart rates were significantly higher than the laboratory ones ($p < 0.05$).

Inclined treadmill tests might also yield higher $\dot{V}O_2$max than horizontal running (Experiment 1). Only the trained subjects walking at high grade for a longer time achieved a higher $\dot{V}O_2$max with the Balke test. For these subjects at least, the Balke test would have overestimated their capacity to run horizontally. The difference is not large however and, the restricted number of subjects calls for caution. The higher $\dot{V}O_2$max with inclined tests is supported by original studies of Taylor **et al.** (1955) and Hermansen and Saltin (1969) but is in opposition to more recent reports of Kasch **et al.** (1976), Froelicher **et al.** (1974), McMiken and Daniels (1976) and Stamford (1975) who reported no difference or even a lower $\dot{V}O_2$max at higher grades. In some of the later studies, however, the maximal grade was not higher than 10% which is more comfortable than the 20% grade frequently encountered with the Balke test. This would be consistent with the absence of difference between the low grade running test and the UM-Track Test (Experiment 2). On the other hand, McArdle **et al.** (1973) and Pollock **et al.** (1977) have reported lower $\dot{V}O_2$ values for the high grade walking Balke test as compared to the ones obtained by low grade running tests. It is speculated that the high grade might sometimes cause local fatigue in the calf and lower back muscles and stop the subject before he reaches his $\dot{V}O_2$max and sometimes result in a higher $\dot{V}O_2$max in well motivated subjects who work longer with additional muscular mass. Obviously, the question is irrelevant with horizontal testing and training.

Another problem associated with maximal and indirect multistage testing is the assumption that $\dot{V}O_2$max is achieved at the last stage. Although it has been reported that $\dot{V}O_2$ not only plateaus but sometimes decreases as the load increases in the last stages of multistage test (Astrand and Saltin, 1961; Bruce, 1974; Froelicher **et al.** 1974; Taylor **et al.** 1963), this mainly occurs in discontinuous multistage tests and is very unusual in continuous ones (Froelicher **et al.** 1974; Taylor **et al.** 1963). The lowering effect itself is small (3-5%) and only occasional in continuous tests (Bruce, 1974).

Data collected in this study were mostly obtained on adult males. If the measurement of the functional capacity or the prescription of running loads are the main purposes of the test, the UM-Track Test could also be done by women and children since flat running is used both in training and testing. If the $\dot{V}O_2max$ is the main focus of the test, predicted $\dot{V}O_2$ will have to be increased by at least 2% for each year of age under 18 years old in both boys and girls (Astrand, 1952 and Daniels **et al.** 1978). Whether or not a sex correction has to be made remains obscure; Bransford and Howley (1977) have reported a lower mechanical efficiency for the women but data by Astrand (1952), Falls and Humphrey (1976) and Bruce **et al.** (1973) indicate similar or even greater mechanical efficiency (see also Figure 1).

Reliability of the UM-TT. This study has indicated that the UM-Track Test is highly reliable (Figure 4) for trained and untrained subjects (35-52.5 and 56-70 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$), for young and middle aged adults (20-30 and 30-40 years old) and for male and female adults. The discrete nature of the test revealed that 9 and 4 subjects out of 60 had a higher and a lower score respectively by 1 Met in the second test. None of the subjects had a difference greater than 1 Met. The 0.97 correlation coefficient and the SD_Δ and S_{yx} of 0.55 Mets or 1.92 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ (Figure 4) are very similar to the values reported by Bruce **et al.** (1973) for their inclined multistage treadmill test ($r = 0.99$, S_{yx} 1.9 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$). The UM-Track Test also appears to be as reliable as the 12-min run test which yielded r of 0.98 for high school boys (Bigbee and Doolittle as reported by Cooper, 1968) and r of 0.72 for high school girls (Martin, 1971).

Table 3. Variation in the oxygen uptake of running or walking as a function of speed and/or grade.

Reference	Intensity[1]	SD[2]	r[3]	S_{yx}[3]	Remarks[4]
HORIZONTAL TREADMILL RUNNING					
Bransford '77	SM		>0.8, >0.97[5]	1.4-2.1	n = 4x10, T & U, M & F, A = 20
Costill '73	SM		0.96	2.5[5]	n = 16, T, M, A = 35
Costill '73	SM		0.95		n = 6, M, marathon runners
Falls '76	SM		0.94-0.97[5]	(3.4-5.4%)[5]	n = 7, T & U, F, A = 20
Margaria '63	SM	(3%)			
Mayhew '77	SM		0.917	3.5	n = 9, T, M, A = 25
Shephard '69	SM	(7.7-12.8%)			n = 14, U, M, A = 26
HORIZONTAL TREADMILL AND TRACK RUNNING COMBINED					
McMiken '76	SM		0.91	2.7	n = 8, T, M, A = 19.5
HORIZONTAL TRACK RUNNING					
Present study	M		0.96	2.8	n = 25, T & U, M, A = 24.4
INCLINED TREADMILL RUNNING OR WALKING					
Bruce '73	SM		0.93		n = ?, U, M & F, Adults, Bruce Test
Bruce '73	M		0.91	3.45	n = 295M + 157F, U, A, Bruce Test
Falls '76	SM		0.86-0.92[5]		n = 7, T & U, F, A = 20, 5%
Froelicher '74	SM	2.0-2.5	0.74	3.92	n = 317, U, M, A = 37, Balke Test
Froelicher '74	M	4.2-4.3	0.69	4.41	n = 708, U, M, A = 32, Balke Test
Pollock '77	M		0.88-0.92		n = 51, U, M, A = 35-55 Bruce, Ellestad & Balke Tests
Present study	M		0.89	3.64	N = 28, T & U, M, A = 25, 12.5%

[1]Regression computed from submaximal loads or maximal loads
[2]Standard deviation, ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ (or % of X)
[3]Coefficient of correlation and standard error of the estimate, in ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ (or % of X)
[4]Remarks, T & U: Trained and Untrained, M & F: Male and Female, A: Age, %: slope of the treadmill
[5]Computed on single individuals

Comparison with other field tests. The predicted VO_2max from the UM-Track Test was on the average similar to the one obtained with other commonly used tests such as the submaximal bicycle Astrand-Ryhming test, the Canadian Home Fitness Test and the 12-min run test, but the SD was much wider for the latter tests indicating a greater intra-individual variation for these tests. In fact, the intra-individual variation between the lowest and highest score raises some doubt about the accuracy of some of these tests when they are used on an individual basis (Figure 5).

Administration of the UM-TT. Although the UM-Track Test is progressive, it is a maximal test and the safety question is important but must not be over-emphasized. The UM-Track Test was administered to more than 3,000 adults following the fitness classes at the University of Montreal and no major or secondary problem was reported. All the subjects filled a medical questionnaire and subjects with a positive questionnaire and/or sedentary subjects over 35 years of age were required to pass a medical check-up and all the subjects trained for two weeks before the test.

Due to the magnitude of the maximal speed achieved by most subjects in their final stage of the UM-Track Test, the test cannot be administered on tracks or perimeters shorter than 200 m unless these are appropriately inclined curves. It is recommended that pace markers be set 50 m apart or less in order to make it easy to follow the pace.

CONCLUSION

It is concluded that the UM-Track Test is accurate, valid, reliable and safe for young and middle-age adults, males and females, whether they are trained or not.

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