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original article

Performance prediction of endurance runners through laboratory and track tests

Predição da performance de corredores de endurance por meio de testes de laboratório e pista

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Abstract – The objectives of this study were: 1) determine and compare physiological indexes from laboratory and track tests (Université de Montréal Track Test - UMTT) in endurance runners; 2) analyze the predictive capacity of VO_2max, vVO_2max and AT with the running performance at 1,500 m, 5,000 m and 10,000 m time trials; 3) analyze the effects of running distance on the relationship between the physiological indexes with aerobic performance. The study included 10 moderately trained endurance runners who performed the following series of tests on different days: 10,000 m, 5,000 m, and 1,500 m time trials on a 400 m track; two maximal incremental tests (laboratory and track) to determine the VO_2max, vVO_2max, and AT. There were no significant differences between VO_2max, vVO_2max and AT determined in both protocols. The multiple regression analysis revealed that vVO_2max was the only index from laboratory associated with running performance at 1,500 and 5,000 m (62 and 35%, respectively). In addition, vVO_2max from UMTT explained the running performance for the same previous distance (78 and 66%, respectively). On the other hand, the AT determined in both incremental tests explained 38 and 52% of performance at 10,000 m time trial, respectively. Thus, the prediction of endurance performance of long distance runners using VO_2max, vVO_2max and AT determined in the laboratory and UMTT tests depends on the running distance.

Key words: Aerobic metabolism; Endurance running; Physiological indexes.

Resumo – *Os objetivos deste estudo foram: determinar e comparar índices fisiológicos obtidos em teste de laboratório e pista (teste de pista da Universidade de Montreal - UMTT) em corredores de endurance; analisar a capacidade de predição do VO_2max, vVO_2max e LAn determinados no laboratório e no UMTT para a performance nas distâncias de 1.500 m, 5.000 m e 10.000 m; analisar os efeitos da distância da prova na relação entre os índices fisiológicos VO_2max, vVO_2max e LAn com a performance. Participaram deste estudo, 10 corredores moderadamente treinados que realizaram os seguintes testes: provas simuladas nas distâncias de 10.000 m, 5.000 m e 1.500 m; dois testes incrementais máximos (laboratório e pista) para determinar os índices VO_2max, vVO_2max e LAn. Não houve diferenças significativas entre o VO_2max, vVO_2max e LAn determinados em ambos os protocolos. De acordo com a análise de regressão múltipla, referente ao teste de laboratório, a vVO_2max foi a única variável selecionada para explicar a performance nas provas de 1.500 e 5.000 m (62 e 35%, respectivamente). Do mesmo modo, dentre as variáveis determinadas no UMTT, somente a vVO_2max explicou a performance nestas distâncias (78 e 66%, respectivamente). Por outro lado, o LAn determinado no laboratório e no UMTT explicou 38 e 52% da performance nos 10.000 m, respectivamente. Pode-se concluir que a predição da performance aeróbia de corredores de endurance moderadamente treinados, a partir do VO_2max, vVO_2max e LAn, determinados em laboratório e no UMTT, é dependente da distância da prova analisada.*

Palavras-chave: *Corridas de endurance; Índices fisiológicos; Metabolismo aeróbio.*

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INTRODUCTION

Maximum oxygen uptake (VO_2max) has an important relationship with endurance running performance[1-4]. However, trained runners may have similar VO_2max values and thus other physiological indexes such as velocity associated with VO_2max (vVO_2max) and anaerobic threshold (AT) can contribute for the success of predominantly aerobic events[5-8]. For example, vVO_2max has shown a close relationship with performance in short, intermediate and long distance races[2-8]. In turn, AT has been considered an essential parameter in assessing aerobic capacity[9] and training prescription[10] and also an important factor in predicting performance in endurance races[1,6,8,11].

However, these indexes are usually determined in laboratory protocols, since there is better control of the environment and greater precision in measurements performed. Thus, one of the disadvantages of laboratory tests is the difficulty in reproducing a situation closer to reality daily experienced by athletes. In this context, the track test at the University of Montreal (UM), proposed by Léger and Boucher[12] is a more specific protocol, since it allows identifying VO_2max and vVO_2max[13,14]. Furthermore, although there are no studies that provide information, it could be hypothesized that, by identifying the heart rate deflection point (HRDP), as proposed by Conconi et al.[15] and Conconi et al.[16], it is possible to estimate AT in UM.

Different studies have analyzed the prediction of aerobic performance of endurance runners using indexes previously mentioned[1-8]. These, however, used single or multiple regression models analyzing the same group of athletes, the relationship between physiological indexes and performance in a single distance, which frequently varies from 1,500 m to 10,000 m[1-8]. Based on these studies, it has been proposed that the running distance and therefore the exercise intensity may influence the relationship between physiological indexes and the aerobic performance of runners[6]. Furthermore, to our knowledge, no study has investigated the endurance performance obtained for the same runners at different distances with two or more indexes determined in laboratory and track tests, particularly using UM.

As the percentage of aerobic contribution and intensity relative to vVO_2max and AT are proportionally different between 1,500 m, 5,000 m and 10,000 m distances[6,17], some hypotheses have been formulated: the relationship between VO_2max and AT vVO_2max indexes (determined in laboratory and in UM) and performance are dependent on the distance (1.500 m, 5.000 m and 10.000 m); the physiological indexes that best predict performance on1.500 m, 5.000 m and 10.000 m running tests are the same in both protocols (laboratory and UM); however, indexes identified in UM have greater capacity to predict performance in 1.500 m, 5.000 m and 10.000 m running tests compared to indexes identified in laboratory tests.

Moreover, the lack of sufficient information in literature about the effects of the distance on the relationship between maximum and submaxi-

mal physiological indexes determined in laboratory and UM with aerobic performance (different distances) reveal the importance of conducting this research. Thus, the aims of this study were: a) determine and compare physiological indexes from laboratory and track tests (Université de Montréal Track Test - UM) in endurance runners; b) analyze the predictive capacity of VO_2max, vVO_2max and AT with the running performance at 1,500 m, 5,000 m and 10,000 m time trials; c) analyze the effects of running distance on the relationship between the physiological indexes VO_2max, vVO_2max and AT with aerobic performance at distances of 1.500 m, 5.000 m and 10.000 m.

METHODS

Subjects

The study included 10 moderately trained runners with at least two years of experience with training and endurance events (28.3 ± 6.8 years and 68.5 ± 8.5 kg, 173.5 ± 7.5 cm and 10.6 ± 3.1% body fat). The study was approved by the Ethics Committee on Human Research of the Federal University of Santa Catarina. Participants were informed and familiarized with all experimental procedures, as well as about risks and benefits, signing the informed consent form.

Experimental procedure

Initially, in an official 400-m track, athletes performed three simulated tests in the following distances: 10,000 m, 5,000 m and 1,500 m. Subsequently, each athlete performed an incremental laboratory test to determine VO_2max, vVO_2max and AT. Finally, to determine VO_2max, vVO_2max and AT in track, protocol proposed by Léger and Boucher [12] (UM) was used. All tests (laboratory and track) occurred in similar climatic conditions (temperature = 23-25ºC; relative humidity = 60-68%), with at least 48 h interval between tests. Athletes were instructed to participate in the study under conditions of total recovery, hydration and nourishment. The experiment was completed in two weeks, with all tests occurring in the same period of the day.

Determination of performance on 10.000 m, 5.000 m and 1.500 m tests

Runners performed simulated tests in a 400-m track on different days at distances of 10,000 m, 5,000 m and 1,500 m. Before each test, athletes were allowed to perform a moderate-intensity warm-up exercise followed by stretching (15 min total).

Determination of VO_2max, vVO2max and AT at laboratory

VO_2max was determined using an incremental protocol on a treadmill (IMBRAMED SUPER ATL, Porto Alegre, Brazil). The initial velocity was 12 km h^{-1} (1% slope) with increments of 1 km h^{-1} every 3 min until voluntary exhaustion[6]. There was a 30 s interval between each stage to collect 25

µl of blood from the earlobe for the estimation of blood lactate using an electrochemical analyzer (YSI 2700 STAT, Yellow Springs, OH, USA). VO_2 was measured breath by breath throughout the protocol from the expired gas (K4b², Cosmed, Rome, Italy), and data were reduced to an average of 15 s. VO_2max was considered as the highest value obtained during the test in these intervals of 15 s. To consider that the subjects reached VO_2max during the test, the following criteria were adopted[18]: 1) respiratory quotient > 1.1; 2) blood lactate concentration ≥ 8 mmol L^{-1}; and 3) heart rate ≥ 90% of maximum heart rate (HRmax) predicted for age. vVO2max was considered as the lowest running velocity in which VO_2max occurred[10]. AT was determined as the velocity corresponding to the fixed lactate concentration of 3.5 mmol L^{-1}, as proposed by Heck et al.[9].

Determination of VO_2max, vVO2max and AT in UM

VO_2max was determined using the incremental test of Léger and Boucher[12] in an official athletics track. The initial velocity was 8 km h^{-1}, with increments of 1 km h^{-1} every 2 min until voluntary exhaustion. The velocity of each stage was controlled by sound signals from a computer and speaker system. Furthermore, the track has been marked with cones every 40 m, and at each sound signal, athletes should be passing near the cones simultaneously. The test was finished when the athlete could no longer maintain the speed required, being considered maximal when the final heart rate was equal to or above 90% of HRmax predicted for age. VO_2max was estimated by equation (mL.kg^{-1}.min^{-1}) = 0,0324x^2 + 2,134x + 14.49; where "x" represents vVO_2max (km h^{-1})[12]. vVO2max was determined as the velocity corresponding to the last stage completed by the athlete. However, if the athlete failed to complete the last stage, vVO2max was determined according to the following equation: vVO2max (km h^{-1}) = speed of the last complete stage (km h^{-1}) + [t (s) / stage duration (s) x incremental velocity (km h^{-1}); where "t" was the time of incomplete stage[19]. AT was the velocity corresponding to the HRDP[15], which was identified using the mathematical method Dmax, as described by Kara et al.[20].

Statistical Analysis

Data are expressed as mean ± SD and normality was verified by the Shapiro-Wilk test. To compare the physiological parameters determined in laboratory and track tests, Student's t test was used for paired samples. Multiple regression analysis investigated the relationship between the running time in the different distances and the physiological indexes in both protocols. To compare the average velocity in the tests with vVO_2max and AT, One-way ANOVA complemented by LSD *post hoc* test was used. In all analyses, significance level of 5% was adopted.

RESULTS

Table 1 shows the physiological indexes obtained in laboratory and UM.

No significant differences were observed between VO_2max, vVO_2max and AT determined in both protocols.

Table 1. Physiological indexes obtained in the incremental test performed at laboratory and UM.

Physiological indexes	Laboratory	UM
VO_2max (mL.kg^{-1}.min^{-1})	64.2 ± **5**.7	65.5 ± **2**.3
vVO_2max (km.h^{-1})	18.4 ± **0**.7	18.6 ± **0**.7
AT (km.h^{-1})	14.9 ± **0**.7	15.1 ± **1**.8
AT (%vVO_2max)	81.2 ± **5**.6	81.0 ± **8**.6

Note: VO_2max = maximum oxygen uptake; vVO_2max = velocity corresponding to maximal oxygen uptake; AT = anaerobic threshold; UM = incremental test track at the University of Montreal[12].

Performance times on 1,500 m, 5,000 m and 10,000 m tests were 4.8 ± 0.2 min, 18.2 ± 0.8 min and 38.6 ± 0.2 min, respectively. The relative values (% vVO_2max and %AT) of velocities adopted in each distance are shown in Table 2. The average velocity in the 1,500 m test (v1,500) showed no significant difference in relation to vVO_2max determined in both protocols. However, the average velocity that runners maintained over the 5.000 m (v5.000) was significantly higher ($p < 0.001$) than AT and significantly lower ($p < 0.001$) than vVO_2max in both protocols. In the distance of 10,000 m, the average velocity maintained during the test (v10.000) was significantly different ($p < 0.01$) from AT determined in laboratory. However, when this physiological index was determined in UM, there was no difference from v10.000.

Table 2. Relative velocity values shown at distances of 1,500 m, 5,000 m and 10,000 m

Distance (m)	Velocity (km.h^{-1})	%vVO_2max (laboratory)	%vVO_2max (UM)	%AT (laboratory)	%AT (UM)
1.500	18.8 ± **0**.8	102.3 ± 2.7	101.2 ± 1.9	126.3 ± 9.0	124.1 ± 8.7
5.000	16.5 ± **0**.7	89.8 ± 3.3	88.7 ± 2.0	110.7 ± 6.6	108.8 ± 6.7
10.000	15.6 ± **0**.6	84.9 ± 3.9	83.9 ± 2.5	104.6 ± 4.2	102.8 ± 5.2

Note: vVO_2max = velocity corresponding to maximal oxygen uptake; AT = anaerobic threshold; UM = incremental test track at the University of Montreal[12].

Tables 3 and 4, respectively, show the physiological indexes determined at laboratory and UM with capacity to predict performance in different distances analyzed. For all cases, the indexes obtained in Léger and Boucher [12] test explained performance better than indexes obtained at laboratory. However, referring to laboratory test, vVO_2max was the only variable selected to explain performance in 1,500 m and 5,000 m tests (62 and 35%, respectively). Similarly, among indexes determined in UM, only vVO_2max explained performance at these distances (78 and 66%, respectively). Furthermore, AT determined in laboratory and UM explained 38 and 52% the performance in the 10,000 m test, respectively.

Table 3. Multiple correlation coefficients of physiological indexes determined in laboratory with performance at distances of 1,500 m, 10,000 m 5,000 m.

Distance	Variables	R^2	p-value
1.500 m	vVO_2max	0.62	0.004
5.000 m	vVO_2max	0.35	0.050
10.000 m	AT	0.38	0.018

Note: vVO_2max = velocity corresponding to maximal oxygen uptake; AT = anaerobic threshold.

Table 4. Multiple correlation coefficients of physiological indexes determined in UM with performance at distances of 1,500 m, 10,000 m 5,000 m.

Distance	Variables	R^2	p-value
1.500 m	vVO_2max	0.78	0.001
5.000 m	vVO_2max	0.66	0.002
10.000 m	AT	0.52	0.001

Note: vVO_2max = velocity corresponding to maximal oxygen uptake; AT = anaerobic threshold.

DISCUSSION

Confirming the hypothesis of the present study, the results found were: the physiological indexes determined in laboratory showed no significant differences from those determined in UM (Table 1); performance prediction from VO_2max, vVO_2max and AT determined in both protocols (laboratory and UM) was dependent on the running distance; physiological indexes obtained in laboratory test that were able to predict performance in the 1,500 m, 5,000 m and 10,000 m tests were similar to indexes obtained in UM; indexes derived from UM had higher ability to predict performance than indexes derived from laboratory tests in the three distances analyzed. However, although the test duration affected the relationship between VO_2max, vVO_2max and AT and the performance of athletes at these distances, it is noteworthy that the aerobic system is prevalent in all tests[17,21].

In relation to VO_2max, no significant difference was found for this index when compared between track and laboratory protocols (Table 1). This is in agreement with other studies that also found no differences between VO_2max determined in laboratory and UM in heterogeneous individuals in terms of training level, age and sex[12,13,22,23]. However, although VO_2max is considered a physiological determinant of aerobic performance in endurance runners, when homogeneous groups of runners are analyzed, this index has shown little discriminatory power of performance in predominantly aerobic events[6]. This was also observed in this study, since there was no correlation of VO_2max with the tests analyzed. One explanation for this behavior may be due to the low variation coefficient of VO_2max (8.4 and 3.5%, respectively to laboratory and track tests).

Additionally, when runners with similar performances and low VO_2max variability are evaluated, difficulty in the association between variables can be found. A low variation coefficient for the range of values

of one or both variables (in this case, test times and VO_2max) determines a correlation coefficient close to zero when variables are associated. Once runners with similar VO_2max are analyzed, it is believed that the group homogeneity can provide more precise information on the capacity of predicting performance by other physiological indexes (e.g. vVO_2max and AT).

Similarly to VO_2max, no significant difference was found for vVO_2max when it was compared between protocols (Table 1). This corroborates studies by Berthoin et al.[13,23], who also found no differences between vVO_2max determined in laboratory and in UM in moderately trained individuals. In contrast, Lacour et al.[18] found in a group of well-trained runners that vVO_2max determined in UM (21.9 ± 1.5 km h^{-1}) was slightly higher ($p<0.05$) than vVO_2max determined in laboratory (21 6 ± 1.6 km h^{-1}). However, it is important to note that in this study[18], the sample consisted of endurance runners of both sexes, which, somehow, might have influenced the results.

In relation to the ability to predict performance, vVO_2max determined in both protocols was the only to explain performance on 1,500 m and 5,000 m tests (Tables 3 and 4). At these distances, vVO_2max determined in laboratory explained 62% and 35% of the performance variability, respectively. However, in a greater proportion, vVO_2max explained the performance variation in 78% for 1,500 m and 66% for 5,000 m.

In relation to the 1,500 m test, this study corroborates other studies that examined the relationship between vVO_2max determined in laboratory and UM and the performance of endurance runners at this distance[6,11,18,24,26]. Lacour et al.[11,18] found a significant correlation between vVO_2max obtained on treadmill and the performance of runners in the 1,500 m test (r = -0.62 and r = -0.90, respectively). Similarly, also when determined in laboratory, vVO_2max explained 67% and 64% of the performance variation in the 1,500 m test for a group of well-trained runners[24] and a group of moderately trained runners[6], respectively. When vVO_2max was obtained through the Léger and Boucher [12] protocol in well-trained endurance runners, Lacour et al. [22] found a high correlation (r = 0.96) between this index and v1,500.

In the 5,000 m test, the results confirm the findings of other studies that investigated the relationship between vVO_2max and the performance of endurance runners at this distance[8,11,25,26]. Tanaka et al.[8] found a significant correlation between vVO_2max and the performance of runners at distance of 5,000 m at different stages of an endurance training program (correlation coefficients between -0.67 and -0.79). Also in the 5,000 m test, Lacour et al.[11] observed significant correlation (r = 0.86) between vVO_2max and v5,000. In addition, when estimated from the submaximal relationship between VO_2 and the running velocity, vVO_2max has also been correlated (r = -0.63) with the 5,000 m test[26]. On the other hand, in a group of moderately trained runners, Mercier and Léger[25] found high correlation (r = -0.98) between vVO_2max determined in UM and the performance in the

of 5,000 m test. However, this high correlation may be explained by the heterogeneous characteristics of the sample [25].

Blood lactate response also shows an important relationship with performance in endurance tests[17]. This was confirmed in this study, since AT was the only index that explained performance in the 10,000 m test (Tables 3 and 4). Moreover, v10,000 was very similar to AT determined in both protocols (Table 2). In fact, AT has shown significant associations with the performance of endurance runners in the 10,000 m test[5,8]. Thus, based on data obtained, it could be inferred that the performance at this distance is highly dependent on aerobic capacity.

However, although being an important physiological parameter of aerobic capacity[17], blood lactate is very difficult to be determined in sports due to several factors (e.g., high costs, invasive procedures, etc.). In contrast, the heart rate response, although still very contradictory[27], has shown a direct relationship with the blood lactate response during exercise[15,16]. Based on this relationship, this study has hypothesized that by identifying the HRDP in the Léger and Boucher[12] test, it would be possible to estimate AT using the method of Heck et al.[9] for incremental protocols with stages of 3 min duration. This could be confirmed, since no significant difference was found for this index when compared between laboratory and UM protocols (Table 1).

CONCLUSION

Based on the results found, it was concluded that the prediction of the aerobic performance in moderately trained endurance runners using VO_2max, vVO_2max and AT (determined in laboratory and in UM) is dependent on the running distance (1.500m, 5,000m 10,000m). Furthermore, no differences were observed in mean values of indexes obtained using the different protocols, although indexes determined in UM showed greater predictive power of performance than those determined in laboratory, thus confirming the ecological validity of the test proposed by Léger and Boucher[12].

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