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ORIGINAL ARTICLE

PHYSIOLOGICAL CHARACTERISTICS OF MIDDLE-DISTANCE RUNNERS OF DIFFERENT COMPETITIVE LEVELS

CARACTERÍSTICAS FISIOLÓGICAS DE CORREDORES MEIO FUNDISTAS DE DIFERENTES NÍVEIS COMPETITIVOS

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ABSTRACT

The objectives of this study were to compare the indexes of aerobic power and capacity, kinetics of O2 uptake and muscle power in two groups of middle-distance runners and verify whether the performance prediction in the 1500-meter run is dependent on the level of training. A total of 21 runners participated in the study: 9 were classified as trained (group 1 – G1) and 12 as moderately trained (group 2 - G2). The following indicators were assessed: 1) 1500-metre run performance; 2) maximal oxygen uptake (VO2max), anaerobic threshold and running speed at VO2max (vVO2max); 3) time limit to reach VO2max at vVO2max; 4) vertical jumps. The main results suggested that the aerobic power and capacity indexes were higher in the G1, whose components proved to be able to differentiate the competitive level of the runners. The vVO2max was the only index to explain the 1500-metre run performance, regardless the level of training.

Keywords: Runners. Aerobic Performance. Muscle Power.

INTRODUCTION

Several studies have been attempting to determine the most appropriate physiological indexes that can be used as a reference for controlling the effects of training and the performance prediction in predominantly aerobic races (BRANDON, 1995; DENADAI, 1995; GRANT et al., 1997; DENADAI; ORTTIZ; MELLO, 2004). Traditionally, the most studied indexes are maximal oxygen uptake (VO2max), the speed corresponding to VO2max (vVO2max), the sustenance time at this intensity (Tlim), besides indexes associated with blood lactate response during submaximal exercise, as the anaerobic threshold (AT).

VO2max is an index of aerobic power that, in general, correlates with performance in events lasting between 3 and 8 minutes, as the 1,500-metre run (BRANDON, 1995); however this index varies widely among individuals in different states of aerobic training and seems not be able to differentiate the level of performance of runners (DENADAI, 1996). According to said author, there is a low correlation between VO2max and performance in highly trained individuals, possibly due to the fact that such index does not always change with training or detraining.

It has been reported that, for high-performance athletes, more important than a high VO2max is exercising at a high intensity relatively to VO2max and keep at it for a long period, especially for competitors of trials carried out at intensities between 95 - 110% of VO2max (CAPUTO et al., 2009). In this sense, indexes such as vVO2max and Tlim seem to differentiate in a more precise way the level of performance of runners (BILLAT; KORALSZTEIN, 1996; DENADAI; ORTTIZ; MELLO, 2004; BILLAT et al., 2009). In addition, these indexes are able to largely explain the performance of trained runners in the 1,500m trial (BILLAT et al., 1996; DENADAI; ORTTIZ; MELLO, 2004).

Besides the indexes related to aerobic power, the time required to reach VO2max

(TAVO2max) in exercises with intensities close to vVO2max has also been considered important for the aerobic performance. According to Denadai and Caputo (2004), trained runners have a shorter TAVO2max than sedentary individuals; this may be considered a control variable of the level of training and aerobic performance.

Differently from the indexes associated with oxygen uptake (VO2), those related to blood lactate response, as the AT, are the ones that best represent the aerobic capacity, demonstrating to have a greater relationship with the performance in long-lasting trials and be able to select the level of performance, including in elite athletes (DENADAI, 1996), although the AT seems not to present great significance for the performance in trials carried out between 3 and 8 min, as the 1.500-metre run (CAPUTO et al. 2009).

In addition, some studies have shown that performance in predominantly aerobic events may be limited not only by central factors, but also by neuromuscular aspects (PAAVOLAINEN, NUMMELA; RUSKO, 1999; NUMMELA et al., 2006). Among these aspects, the capacity of using elastic energy in stretch-shortening cycle (SSC) is considered an important mechanism to optimize both muscle power (KOMI; GOLLHOFER, 1997; MERO; KUITUNEN; KOMI, 2001) and VO2 economy in races (GUGLIELMO; GRECO; DENADAI, 2009). According to Bosco (1999), the level of muscle power and the capacity of using SCC can be assessed through performance in counter movement vertical jump (CMJ), widely used to control the effects of training and performance prediction of runners (HENNESSY; KILTY, 2001; MIGUEL; REIS, 2004; SMIRNIOTOU et al., 2008).

Knowing the importance of determining the physiological markers that can predict aerobic performance and highlight the athletes with the highest performance, this study aimed: 1) to analyze and compare the level of performance in the 1.500-metre run, the indexes of aerobic power (VO2max, vVO2max, Tlim), of aerobic capacity (AT), of VO2 kinetics (Tau, VO2 amplitude, TAVO2max), and also the level of muscle power, in two groups of middle distance runners: one of trained and one of moderately trained, 2) to verify whether the performance prediction in the 1500-metre run is dependent on the level of training of the runners.

METHODS

Subjects

This study counted with 21 middle distance runners, divided into two groups: group 1 (G1), composed of 9 runners considered trained, federated, with experience in competitions at state and national levels, all male (18.1 ± 0.9 years, 64.4 ± 11.2 kg, 171. 9 ± 11.2 cm, 7.1 ± 1.9% of body fat). Such athletes used to train 6 times a week, with an average volume of training of 70 km /week. Group 2 (G2) was composed of 12 runners considered moderately trained, with experience in regional competitions only, all male (28.36 ± 6.47 years; 68.67 ± 8.05 kg; 173.77 ± 7.23 cm, 10.62 ± 2.95% of body fat). The runners trained with a frequency of four times a week, with a course of about 40 km for said period. The type of selection of athletes was the intentional non-probabilistic, taking as a criterion for selection the participation in at least one competition in the year when the assessment occurred. For the division of the groups (G1 and G2), their competitive level was used as a criterion.

Procedures and Instruments

Before the data collection, the athletes were informed about the objectives of the study. Subsequently, they signed the informed consent. The project was approved by the Ethics Committee of the Federal University of Santa Catarina (protocol n. 319/07).

The assessments were conducted in a laboratory environment and a running track, over four days, in the following order: trial simulation for performance determination in the 1500-meter run; anthropometric assessment and maximal incremental test; time of exhaustion and vertical jumps.

The tests were performed with a minimum interval of 24 hours, always respecting the same time of day. All participants were oriented not to perform intense trainings during the period of collection and attended fed and hydrated for the assessments.

Anthropometric assessment

The procedures for the anthropometric measurements followed the protocols defined by Petroski (2007). Body weight and height were measured with a digital scale, Toledo® brand, with 100g of precision, and a stadiometer with a precision of 1 mm, respectively. The skinfold thickness was measured through a Cescorf® adipometer, with a resolution of 0.1 mm. From such measurements, the body density was calculated according to the Jackson and Pollock's equation (1978) and, subsequently, the percentage of fat was estimated through the Siri's equation (1961).

Performance determination

After a warm-up (submaximal trot of 5 min), the athletes simulated a 1500-metre run on an official running track, in order to obtain the performance in this trial (P1500). The time was recorded manually.

VO2max, vVO2max and AT determination

An incremental running test was performed on a treadmill (Imbramed Millenium 10,200, IMBRAMED ®, Porto Alegre, Brazil), with initial speed of 12 km/h^{-1} and 1% of inclination, with increments of 1 km/h^{-1} at every 3 min, until spontaneous exhaustion. Between each stage, there was an interval of 30 seconds for blood collection from the earlobe to measure blood lactate dosages. VO2 was measured, breath by breath, from the expired gas through a gas analyzer ($K4b^2$, COSMED, Rome, Italy), by reducing the data to means of 15s. The blood samples were stored in *eppendorffs* tubes and then analyzed in an electrochemical analyzer (YSI 2700 Stat Select, Yellow Springs, OH, USA). The equipment was previously calibrated according to the manufacturer's recommendations.

VO2max was considered as the highest value obtained during the test, during the intervals of 15s. To verify whether the subjects reached VO2max during the test, the criteria proposed by Taylor et al were adopted. (1955). The vVO2max was considered as the lowest running speed in which VO2max occurred (BILLAT; KORALSZTEIN, 1996). The running speed associated with the AT (sAT) was determined by the fixed lactate concentration of 3.5 $mmol.l^{-1}$ (HECK et al., 1985).

Tlim and TAVO2max determination

For Tlim determination, a protocol of continuous loads on treadmill was used. Initially, the subjects performed a 7min warm-up, at an intensity corresponding to approximately 60% of vVO2max. Subsequently, after a 5min recuperative interval, the speed of the treadmill was adjusted to 100% of the previously determined vVO2max and the subjects were verbally encouraged to maintain exertion to exhaustion. VO2 was measured continuously, breath by breath, throughout the protocol from the expired gas through a $K4b^2$ gas analyzer. The Tlim was considered as the total time of maintained exertion at vVO2, which was expressed in seconds.

The time required to reach VO2max (TAVO2max) during the Tlim was obtained from the analysis of the kinetics of the VO2 increase to VO2max, described by a monoexponential function calculated through the $K4b^2$ software, according to the equation:

$VO_2(t) = VO2rest + A \times (1 – e - (t/\hat{o})$.

In which: VO2 (t) is the oxygen uptake within time t; VO2base is the oxygen uptake in the beginning of the test; A is the amplitude in the oxygen uptake (VO2asymptote - VO2base) and ti is the time constant (defined as the time required to reach 63% of A).

Given that VO2 reaches its maximum value at 99% of the asymptote (VO2rest + A), the time (t) required for this is 4.6 times the ti constant (63% of A); thus, TAVO2max was defined by: 4.6 x ti, expressed in seconds and percentage of the Tlim.

Muscle power determination

The level of muscle power of the runners was assessed from the performance achieved (height) in the vertical jump called Counter Movement Jump (CMJ) (BOSCO, 1999). The CMJ protocol consists of starting from a standing position, with the hands on the hips, and perform a jump with countermovement, which is an acceleration downward the center of gravity, flexing the knees at 90°, approximately. In this jump, it occurs the stretch-shortening cycle (SSC) of the agonist muscles of the movement. As a measuring tool, it was used a platform of piezoelectric force (Quattro Jump 9290AD, Kistler ® Instrument AG, Winterthur, Switzerland). The height of the jump was calculated by the double integration of the vertical force of reaction of the ground, measured by the platform. Three attempts were made, out of which the best result was considered for the analysis.

Statistical analysis

Descriptive statistics (mean and standard deviation) was used to present the results. The data normality was verified through the Shapiro-Wilk test. Subsequently, t test for independent samples was applied to compare the variables in both groups. In order to verify the contribution of the variables analyzed in the P1500, a multiple regression analysis was carried out, with the step-wise method for selection of the variables. The adopted significance level was 5%. The SPSSTM, version [11.5] for Windows, statistical analysis package was used for analysis.

RESULTS

As shown in Table 1, the trained runners presented a higher level of performance (time and average speed) in the 1,500-meter run in relation to the runners of the group 2, of moderately trained. Both groups ran the 1.500m at an average speed above vVO2max, but with a higher percentage in the G1 (5.78%) compared to the G2 (2.37%).

Table 1 - Mean values ± SD of the performance in the 1,500-meter run (time of trial, absolute and relative speed in relation to vVO2max)

	G1 (n=9)		G2 (n=12)	
	Mean	SD	Mean	SD
P1500 (s)	257	6.08	288.08*	11.56
P1500 ($km.h^{-1}$)	21.02	0.5	18.77 *	0.75
P1500 (%vVO2max)	105.78	2.76	102.41*	2.68

P1500: performance in the 1.500m trial; * significant difference between groups

Table 2 displays the values of the variables obtained in the incremental test (VO2max, vVO2max, vAT), in the continuous load test (Tlim and kinetic parameters of the VO2) and the CMJ performance, indicator of muscle power. As shown by the results presented in table 2, the indexes related to the aerobic system (VO2max, vVO2max, Tlim and VLAN) prove to be significantly higher in the G1. The other indexes - CMJ, Tau, and TAVO2max and VO2 amplitude (in absolute values) - were similar between both groups, and the latter, when expressed in % of the Tlim, was higher in the G2.

Table 2 – Mean values ± SD of the physiological variables VO2max, vVO2max, Tlim, vLAN, kinetic of VO2max and of the performance in the CMJ.

	G1 (n=9)		G2 (n=12)	
	Mean	**SD**	**Mean**	**SD**
VO2max (ml.kg 1.min ^{1})	69.99	3.93	64.87*	3.74
vVO2max (km.h^{-1})	19.89	0.78	18.33*	0.65
Tlim (s)	424.56	47.24	350.75*	65.11
Tau (s)	32.75	6.01	32.61	5.57
Amplitude VO2 (ml.kg 1.min ^{1})	57.68	8.58	54.80	9.62
TAVO2max (s)	150.65	27.64	150.01	25.61
TAVO2max (%Tlim)	35.5	6.53	43.74*	9.23
sAT (km.h^{-1})	16.57	1.31	15.07*	0.86
CMJ (cm)	43.32	6.91	41.11	3.84

VO2max: maximal O2 uptake; vVO2max: speed corresponding to VO2max; Tlim: sustenance time at vVO2max; TAVO2max: time required to reach VO2max; vLAN: speed referring to the anaerobic threshold; CMJ: counter movement jump; * significant difference between groups

According to the multivariate regression analysis, vVO2max was the only variable able to explain the variation of the performance for both G1 (58% of the P1500) and G2 (57% of the P1500).

Table 3 – Multiple linear regression among the analyzed variables and the P1500

	Independent variable	**R^2**
P1500 (G1)	vVO_2max	0,58
P1500 (G2)	vVO_2max	0,57

P1500: performance in the 1500-meter run; vVO2max: speed referring to VO2max

DISCUSSION

One of the objectives of this study was to verify which physiological markers are able to differentiate the level of performance of middle-distance runners. The main results suggested that the indexes of power and aerobic capacity are significantly higher in runners of higher level, and it is possible to state that these found differences probably result from the effects of training loads. It is noteworthy that genetic aspects, a factor not controlled in this study, should also be considered.

VO2max is considered the physiological index that best represents the aerobic power of a subject (BASSETT; HOWLEY, 2000); endurance athletes use to present values 1.5 to 2 times higher than healthy subjects (DENADAI, 1995). In the present study, trained runners presented values superior to those of the moderately trained athletes, of lower competitive level, proving to be an index able to differentiate both groups.

According to evidence pointed out in the literature (DENADAI, 1995; DENADAI, 1996), this index varies widely among subjects who have different levels of aerobic fitness and seems not to be able to differentiate effectively the level of performance of runners. Broadly speaking, VO2max correlates with performance in events lasting between 3 to 8 min, as the 1.500m trial (BRANDON, 1995); however, there is a low correlation between VO2max and the performance of highly trained athletes, possibly due to the fact that VO2max does not always change with training or detraining (BILLAT et al., 1994). According to Denadai, Ortiz and Mello (2004), performance improvement in these subjects possibly derives from neuromuscular and metabolic adaptations, since the central oxygen supply is limited by the cardiac output, which prevents VO2max to continue to increase with the effect of the training.

Thus, it is possible to say that the highest values of VO2max in the G1 do not explain, by themselves, a better performance in the 1,500m of this group.

It has been reported that, for athletes of higher level of performance in predominantly aerobic trials, in addition to a high value of VO2max, it is necessary to be able to exercise at a high percentage of VO2max (CAPUTO et al., 2009). In this sense, vVO2max is considered one of the best indexes for aerobic performance prediction. In the present study, such variable was able to explain 58% and 57% of the P1500 in the G1 and G2, respectively. Based on this, it is possible to state that it is able to explain the performance in such trial whatever the level of training of the runners. Our results are in agreement with those found by Billat et al. (1996) and Denadai, Ortiz and Mello (2004), who also verified that vVO2max was able to explain the performance in the 1,500m of highly trained and well trained runners, respectively.

The values of vVO2max obtained in the present study by trained athletes were higher (19.89 $km.h^{-1}$) than those found within the moderately trained group (18.33 $km.h^{-1}$). This difference indicates that such index is modified according to the training level and thus may be able to differentiate the competitive level of the runners, since highest aerobic power (VO2max) of the G1 is obtained with a superior speed in relation to the G2.

How much each physiological index represents of the overall performance will depend on the duration of the trial and, therefore, of the relative intensity that can be maintained throughout it (%vVO2max). The average running speed in the 1,500m of both groups was close to vVO2max, which indicates the effective participation of the aerobic power in this trial. Nevertheless, in the G1 the sustained speed in the running was superior (105.78%) in relation to the G2 (102.41%). A previous study (DENADAI; ORTIZ; MELLO, 2004) reported similar values of relative speed for well-trained athletes in the 1,500 trial (106.7% of the vVO2max). Perhaps, an explanation for a greater relative intensity of the G1 relies is on the difference in the levels of anaerobic capacity of the groups. This hypothesis is supported by the fact that the running speed close to the VO2max is not determined only by the aerobic metabolism, but also by the anaerobic system (NOAKES, 1988; FAINA et al., 1997), which may influence the level of performance in said running.

Besides the speed associated with VO2max, the time at which it can be maintained by the athlete (Tlim) is considered an important performance discriminator in trials, as the 1.500m (BILLAT et al., 1996). In the present study, the values of Tlim of the athletes of the G1, with higher vVO2max, were higher than those in the G2, whose vVO2max was lower. Different results were observed by Denadai and Caputo (2004), in whose study endurance trained runners presented a higher vVO2max when compared with sedentary individuals, although the Tlim of the athletes has been lower.

A factor that may explain such occurrence is the wide variability of the Tlim that exist among subjects with similar vVO2max, which can reach a coefficient of variation of 25% (BILLAT; KORALSZTEIN, 1996). In the case of the present study, although vVO2max is higher in the G1 in relation to the G2, these values are much closer if compared to the studies of Denadai and Caputo (2004), in which vVO2max of the athletes was much higher (19 4 $km.h^{-1}$) than of the sedentary subjects (12.8 $km.h^{-1}$).

This wide variability of Tlim in runners with similar aerobic power can be attributed to the participation of the anaerobic metabolism during exercise. Faina et al. (1997) verified that the Tlim was directly related to the anaerobic capacity of the athletes, which can account for approximately 16% of the total energy production. Thus, as previously reported, it can be assumed that trained athletes of the present study have higher anaerobic capacity, allowing a longer time of exhaustion, even at speeds higher than the speed of moderately trained athletes.

Besides being an index of performance prediction, the Tlim in the vVO2max is used to control the duration of the stimuli during a training with intervals in order to keep exercising as long as possible at VO2max (BILLAT et al., 1999). According to the authors, there is a relatively wide variation in the times of these stimuli; therefore, it has been suggested TAVO2max as a way of individualizing these durations of exercise (HILL; WILLIAMS; BURT, 1997; HILL; ROWELL, 1997). In the present study, TAVO2max was at 35 and 43% of the Tlim for G1 and G2, respectively, percentages that are relatively lower than the 49% reported by Caputo and Denadai (2004), being found values that reach 80% of the Tlim (HILL, ROWELL, 1997).

No significant differences have been found in the parameters of VO2 kinetics between both groups of runners. The absolute values of TAVO2max obtained in this study were similar to those reported by Caputo and Denadai (2004), but relatively lower when expressed in percentage of the Tlim. It might be expected that the runners of the G1 had lower Tau and TAVO2max than the athletes of the G2, because it is reported that the effect of aerobic training accelerates the response of VO2 in the beginning of the exercise, reaching VO2max earlier (DEMARLE et al., 2001); however, this difference seems to be noticeable only when comparing subjects of very different aerobic performance levels, as the findings by Denadai and Caputo (2004), who compared trained athletes with sedentary people.

Besides the physiological markers related to the VO2, blood lactate responses to the exercise, as the LAn, are also used as an index of aerobic performance prediction and control of training (COYLE, 1995; JONES, 1998; BENEKE, 2003). In the present study, the VLAN was significantly higher in the G1, which indicates that the group is best conditioned regarding the aerobic capacity. In this way, it possible to say that this index changes with predominantly aerobic training performed by runners, and it is able to differentiate the level of performance of middle-distance runners.

It should be highlighted that in the 1.500m trial, when performed at intensities close to 100% of VO2max, the aerobic power is considered the main performance predictor, according to the results of this study. At these distances, the indexes associated with the blood lactate response (aerobic capacity) have a smaller share in the performance (CAPUTO et al., 2009), and does not need, therefore, to be the main objective of the training.

The last variable analyzed in this study refers to the neuromuscular characteristics, more specifically the muscle power of the lower limbs assessed by the CMJ performance. No significant differences in this variable between G1 and G2 have been found, indicating that lower limbs power was not able to differentiate the performance in the 1500m in these different groups of middle distance runners.

On the other hand, recent studies have shown that the power and muscle strength seem to contribute significantly to performance in predominantly aerobic trials (NUMMELA et al., 2006; GUGLIELMO; GRECO; DENADAI, 2009). According to a previous study (PAAVOLAINEN; NUMMELA; RUSKO, 1999), aerobic training, associated with power training, is able to improve performance in endurance trials, through mechanisms such as reducing the time of contact with the ground and during the stride and a better use of the SCC. In turn, Guglielmo, Greco and Denadai (2009) reported that the maximum strength training in association with the aerobic training seems to be more effective for improvements in the aerobic aspects of runners, as, for example, running economy. Thus, the assessment of the maximum force with the use of the 1-MR (one maximum repetition), used in said study, can be a good strategy for the control of training.

Some limitations may be associated with the type of cross-sectional analysis carried out in the present study. The main ones to be mentioned would be the lack of control on the possible influences of genetic load and the specific type of training performed by the runners, factors that were not controlled in this investigation.

CONCLUSION

Based on the results of this study, it can be concluded that middle distance runners with a higher level of performance in the 1,500m trial presented higher VO2max, vVO2max, Tlim and VLAN than moderately trained runners. This indicates that both aerobic power and capacity change according to the level of training, proving to be able to differentiate the level of performance in the 1,500-meter run. The parameters of VO2 kinetics and muscle power of the lower limbs did not differ in both groups, suggesting that such aspects do not distinguish the performance in this trial, which may occur, possibly, only in more heterogeneous groups of runners. Finally, it is concluded that vVO2max was able to explain the performance in the G1 and G2, that is, it proved to be independent on the level of training of the runners.

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