Relationship between physiological indicators obtained in ergospirometry test in cycle ergometer of upper extremities and performance in canoeing

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ABSTRACT

Evaluation of aerobic fitness indicators in canoers reveals functional characteristics acquired through specific training, which can be related to competitive performance. Thus, the aim of the present study was to evaluate functional evaluators obtained in ergospirometry test of young canoers, as well as to verify the relationship of these variables with performance in 200, 500 and 1000 m distances. The sample consisted of 12 male athletes (17.6 ± 2.1 years; 175.7 ± 2.5 cm; 68.3 ± 6.3 kg) through a test in cycle ergometer of upper extremities for determination of oxygen uptake in the ventilatory threshold 1 (VT_1 – 1.8 ± 0.4 L/min), in the ventilatory threshold 2 (VT_2 – 2.9 ± 0.4 L/min) and $\dot{V}O_2$peak (3.5 ± 0.4 L/min). The test began with a 17 W load, with 17 W/min increments until voluntary exhaustion. The athletes have been also submitted to specific tests in K-1 individual canoe in a lake, with the purpose to reach the lowest times in the referred distances (times equivalent to 47.6 ± 4.3, 122.0 ± 9.0 and 239.5 ± 12.6 s, respectively). The Spearman-Rank correlation test was used (*rs*), with significance level set at 5%. Moderate correlation was observed between VT2 and time in the 1000 m (rs = –0.685), $\dot{V}O_2$peak and time in the 500 m (rs = –0.699) and $\dot{V}O_2$peak and time in the 1000 m) *rs* = –0.734). Therefore, it is concluded that VT_2 and $\dot{V}O_2$peak obtained in cycle ergometer of upper extremities, and expressed in absolute terms, predict performance in 500 and 1000 m canoeing events and can be potentially applied in evaluation of canoers.

INTRODUCTION

In the majority of sports modalities, competitive performance depends on optimum and/or maximal multiple physical capacities. Therefore, the morpho-functional improvement of the body, obtained from the planned imposition of workloads in the long run, has as aim to reach progressively higher performance levels. However, the validity of this thinking is only sustained when the training stimuli result is relevant in biological adaptations or specific to the chosen sports modality.

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Approved in 26/4/07.

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Keywords: Ventilatory thresholds. Oxygen uptake peak. Canoeing.

Several studies have focused on establishing relationships between morpho-functional indicators and sportive performance. The aim is to determine prediction, physiological and morphological factors of competitive result, as well as to discriminate variables which are able to be prioritized and periodically evaluated in training. In canoeing, some studies of this nature have been already conducted[1-3]. Nevertheless, due to the fact that competitive distances include from very short distances (200 m) to very long ones (42.000 m), it is inferred that there is heterogeneity in the prediction physiological variables in competition. In other words, runner specialists in the different distances should present differentiated physiological and anthropometric characteristics. Concerning international level, male adult athletes perform the 200, 500 and 1.000 m events approximately in 38, 95 and 205 s, respectively.

Currently, among men, the Olympic velocity canoeing events are of 500 and 1.000 m. In these distances, it is estimated that the percentage contributions of the aerobic metabolism in the energetic transfer among athletes from the cadet and junior categories are of approximately 60% and 80%, respectively, for times of 151.4 ± 16.5 s and 315.8 ± 33.6 s[4]. Therefore, it is expected that aerobic aptitude indicators of upper extremities have significant participation in performance in these distances, having thus predictive capacity over the times of these events.

Among the aerobic variables commonly used in performance prediction models and in the evaluation of athletes, the most widely used are the oxygen uptake peak ($\dot{V}O_2$peak), the metabolic transition thresholds, the aerobic intensity/maximal load, the $\dot{V}O_2$ submaximal (indicator of movement savings) and/or submaximal heart rate indices. The verification of the relationship of at least part of these variables with specific performance in canoeing still needs to be verified.

Therefore, the aims of this study were: (a) to evaluate aerobic aptitude indicators of young canoers; and (b) to verify the relationship of these variables (with and without allometric correction) with performance in 200, 500 and 1.000 m distances.

METHODS

Subjects

The sample consisted of twelve young canoers (17.6 ± 2.1 years; 175.7 ± 2.5 cm; 68.3 ± 6.3 kg), with competitive experience of at least one year. This sample consisted of athletes who had won medals in velocity and marathon national championships, in the cadet and junior categories; some of them had also participated in international championships. All subjects after having read and signed an informed consent form both from the participant and his responsible one, if they were under 18 years old, were submitted to two stages of evaluation: (1) ergospirometric test in cycle ergometer for upper extremities, (2) tests in a lake, composed of maximal efforts in pre-set distances, completed in K-1 individual boat (5.20 m long, 12 kg heavy). The athletes were in a regeneration period after the main velocity competition.

Ergospirometric test of upper extremities

The progressive effort test was conducted in a cycle ergometer with mechanical resistance Monark®, adapted for upper extremities exercise. The cycle ergometer was attached over a table. The pedals were substituted by brass knuckles which allowed that the hands could be adjusted over them. The evaluated individual was then accommodated on a regular chair, placed behind the cycle ergometer. This configuration allowed that the most distal portion of the pedaling cycle was reached with arm approximately parallel to the ground and elbow almost extended. A digital odometer was installed and placed on the view span of the evaluated individual in order to have the velocity controlled.

The ventilatory variables were determined with the use of a VO2000® (*Aerosport Inc.*) apparel. The equipment for gas exchange was calibrated before each effort test. The calibration was performed from the environment gas sample (20.9% of O_2 and 0.04% of CO_2) and from the sample derived from a cylinder with known O_2 (17%) and of CO_2 (5%) concentration. Moreover, the gasses flow for the apparel was calibrated from a three-liter syringe, according to manufacture's standardization. The apparel was adjusted in order to be able to perform the expired gases analyses at every ten seconds. The laboratory temperature was kept between 20-21°C.

Before the beginning of the test, the participant would remain seated for three minutes for measurement of the rest ventilatory variables. After that, he pedaled for three extra minutes with no external resistance. The progressive test was conducted with no pause and initial load of 17 W, with load increments of 17 W per minute, until voluntary exhaustion. The rotation velocity of the pedal was set at 68 rotations per minute. The investigators would verbally motivate the volunteers. The mean of the $\dot{V}O_2$ values reached in the three last measurements previous to exhaustion was considered the $\dot{V}O_2$peak.

The ventilatory thresholds were calculated according to criteria promoted by Wasserman[5] and Simon *et al.*[6]. The oxygen uptake in the ventilatory threshold 1 (LV_1) was determined from the increase of the O_2 equivalent ventilatory ($\dot{V}E/\dot{V}O_2$) with no concomitant increase of the CO_2 ventilatory equivalent ($\dot{V}E/\dot{V}CO_2$). The oxygen uptake in the ventilatory threshold 2 (LV_2) was determined from the increase of the $\dot{V}E/\dot{V}CO_2$. The determinations were made through visual analysis of the ventilatory data, graphically plotted, which were registered through the consensus of three experienced evaluators.

Velocity canoeing tests

The velocity canoeing tests were performed within a period of two weeks. It comprised the ergospirometric tests of upper extremities. Previously to all kayak tests there was a brief warm-up in which the participants completed 1.000 m at rhythm freely chosen. After rest of approximately five minutes, they were lined at the exit of the distance to be completed at the day. The distances were 200, 500 and 1.000 m, marked in a lake. The tests were performed at different days which were possibly performed at the same period of the day and with similar climate characteristics (preferably with no strong wind in favor or against the boats itinerary). The sequence was random. The athlete was asked by hand signal of the evaluator to perform a sprint at maximal velocity for the respective distance. The athletes were evaluated in groups in order to stimulate competition and motivate them to try their best performance. The time was registered with a manual lap timer with seconds' precision.

Statistic treatment

Descriptive statistics was performed for presentation of the data results (mean ± standard deviation) for the studied variables. The ratios between the physiological indicators obtained in the ergospirometric test and performance in the different distances in canoeing were verified by Spearman-Rank correlation (*rs*), due to non-parametric characteristics of distribution of part of variables. The significance level adopted to consider the significant correlations was of $P < 0.05$.

RESULTS

In table 1 the results obtained by the athletes in the progressive effort test performed at cycle ergometer of upper extremities are presented. Relatively high values of $\dot{V}O_2$peak as well as of the ventilatory thresholds were observed, both in absolute and relative terms concerning body weight.

TABLE 1
Description of the aerobic indicators obtained by the canoers in progressive test in cycle ergometer of upper extremities. The results are presented as mean ± standard deviation

	LV_1	LV_2	$\dot{V}O_2$peak
$\dot{V}O_2$ (L/min)	1.8 ± 0.4	2.9 ± 0.4	3.5 ± 0.4
$\dot{V}O_2$ (ml/kg/min)	26.5 ± 6.5	42.0 ± 6.2	51.9 ± 5.6
$\dot{V}O_2$ (%$\dot{V}O_2$peak)	51.7 ± 14.4	81.2 ± 11.8	–

In figure 1, the functional division of the effort domains is represented according to the criteria adopted by Gaesser and Poole[7]. The ventilatory $\dot{V}O_2$peak thresholds are expressed in relative terms concerning body weight. The $\dot{V}O_2$peak was assumed as threshold higher than the severe threshold, and LV_1 and LV_2 as transition points between the moderate and intense domains, and intense and severe, respectively.

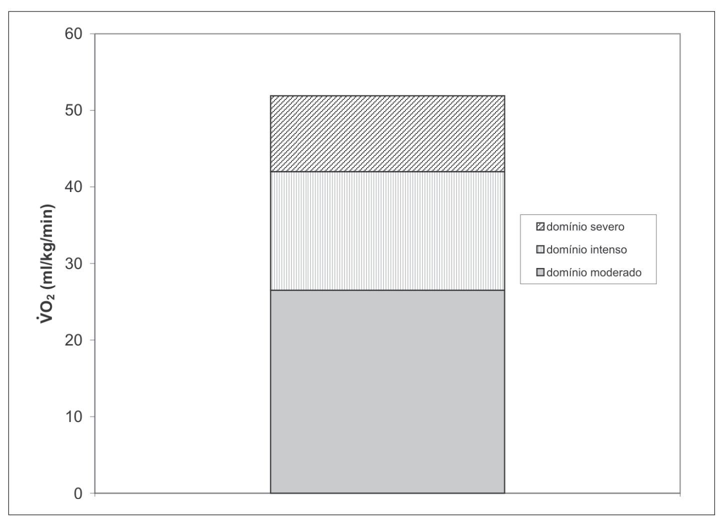

***Figure 1** – Effort domains of the group of canoers according to the criteria adapted from Gaesser and Poole (1996). The transitions and superior threshold are physiologically determined by the $\dot{V}O_2$ mean of the group in the ventilatory thresholds and by the $\dot{V}O_2$peak.*

In table 2, the mean durations of the maximal efforts performed in the 200, 500 and 1.000 m distances are presented.

TABLE 2
Times obtained in the velocity maximal tests by the canoers. The results are presented as mean ± standard deviation.

	200 m	500 m	1.000 m
Time (s)	47.6 ± 4.3	122.0 ± 9.0	269.5 ± 12.6

In table 3 the correlations between the capacity indicators (LV_1 and LV_2) and aerobic power ($\dot{V}O_2$peak), obtained in the ergospirometric test, as well as the times registered in the 200, 500 e 1.000 sprints are presented. The variables of the ergospirometric test are presented in absolute terms.

TABLE 3
Matriz of Spearman-Rank correlations (*rs*) of the aerobic indicators (in l/min) obtained by the athletes in progressive test in cycle ergometer of upper extremities and the durations (T) of the maximal tests performed in the 200, 500 and 1.000 m distances in canoeing

	LV_1	LV_2	$\dot{V}O_2$peak
T200 m (s)	–0.106	–0.460	–0.517
T500 m (s)	0.014	–0.367	–0.699*
T1.000 m (s)	–0.483	–0.685*	–0.734*

* $P < 0.05$

It has been observed that LV_1 does not significantly correlate with any of the specific performance indicators. On the other hand, LV_2 moderately correlated with the time in the 1.000 m, while the $\dot{V}O_2$peak presented moderate negative correlations with the time of the 500 and 1.000 m events simulations. Non-significant correlations were observed when the values of the aerobic indicators were expressed in relative terms concerning body weight (data not shown).

DISCUSSION

This study had as aim to describe the aerobic aptitude profile of canoers of national level, who in its majority are athletes from the cadet and junior categories, through metabolic transition thresholds detected by the ventilatory responses as well as the $\dot{V}O_2$peak, and use them in the prediction of specific performance in velocity events.

The metabolic thresholds are traditionally considered indicators of aerobic capacity, since they correlate with long duration performance. Concerning the $\dot{V}O_2$peak terms, the LV_1 and LV_2 values of the studied sample were approximately 50% and 80%. These are typical percentages found in non-athletes[6,8]. However, in canoeing athletes, it is possible to find LV_1 at around 85% of the $\dot{V}O_2$peak, in ergometer-kayak[9-10]. Curiously, when they are evaluated in cycle ergometer for lower extremities, these canoers present reduction of about 10% in this percentage, showing the influence of the adaptative specificity in the evaluation of the training effects. The discrepancy between the results reached by the athletes from our sample and the ones studies by Bunc and Heller[9] and Bunc *et al.*[10] may be credited to the reduced number of training years of the athletes of the present study (3.1 ± 1.9 years). In the long run there could have been comparison between the aerobic capacity indicators. Moreover, other factors such as age and competitive level should be considered. Methodological issues should also be considered, once Bunc and Heller[9] and Bunc *et al.*[10] used test protocols with initial load relatively high, and the linearity break of the relationship between pulmonary ventilation and $\dot{V}O_2$ as determination criterion for the LV_1. One should not forget the possibility that the methodology by Bunc and Heller[9] and Bunc *et al.*[10] has generated estimate of LV_2, and not LV_1. The protocols started at around 40-60% of the power generated in one minute of maximal effort, which could already be in loads above the LV_1, making that the pulmonary ventilation breakage corresponded to the LV_2. This fact would practically equal the athletes studied by us to the ones reported by the mentioned author. The fact that Fry and Morton[2] have found LV_1 at 58% of $\dot{V}O_2$peak in athletes selected in his country corroborates our possibilities.

The athletes studied by Bunc and Heller[9] were older and presented high competitive level within the European continent. It is interesting to note that the $\dot{V}O_2$peak (51.9 ml/kg/min) of the male groups evaluated by Bunc and Heller[9] was equal to the one studied by us. Nevertheless, since they were taller and heavier, the athletes from Bunc and Heller[9] reached higher levels of $\dot{V}O_2$peak in l/min. There is no knowledge of previous studies which have measured the LV_2 in canoeing athletes. However, one may speculate that a similar pattern to the LV_1 would be found. Therefore, it is probable that the percentage improvement of the ventilatory thresholds demand some years to come up completely.

The $\dot{V}O_2$peak concerning the body weight reached by the canoers (51.9 ± 5.6 ml/kg/min) may be considered high, since comparatively it was higher than the values reported in young individuals, in its majority non-athletes, who performed maximal test in cycle ergometer for lower extremities (46.7 ± 8.5 ml/kg/min), in a previous study conducted by our group[11]. Besides the greater muscular mass used by the lower segment of the body in a maximal exercise, which would justify a wide advantage of the legs in uptaking oxygen, there is the extra factor that the O_2 cogency in the upper extremities is lower than in the lower extremities, which can be credited to factors such as heterogeneity in the blood flow distribution for the different muscles or functional portions of the same muscle, times of mean transit in the differentiated capillars, as well as areas of different diffusion[12].

It is estimated that individuals who belong to athletic groups who primarily train the upper extremities or secondarily train for their events (gymnastics, swimming, fights and yachting) present $\dot{V}O_2$peak in exercises with the arms of 40.1 to 41.6 ml/kg/min[13]. Therefore, the canoers of this study are in a higher level compared with the athletes of other modalities. Generally, the relationship between $\dot{V}O_2$peak of arms and legs is between 0.82 and 0.90 in these population samples. Unfortunately, in this investigation, this relationship has not been calculated. Among young sedentary individuals, the $\dot{V}O_2$peak of upper extremities varies from 30.4 ml/kg/min[13] to 34.2 ml/kg/min[14], suggesting hence that the canoers present great adaptability of the cardiorespiratory functions when facing training stimuli for upper extremities.

The canoers of this study presented $\dot{V}O_2$peak equivalent to around 88% of the values reported by Fry and Morton[2] in high level Australian athletes (59.2 ± 7.1 ml/kg/min) and approximately 89% of the values obtained by Tesch[15] in canoers of the Swedish team in the 80's from last century (58.4 ± 3.1 ml/kg/min). On the other hand, the canoers from our sample had aerobic power levels similar to the members of the British team (52.6 ± 4.9 ml/kg/min), in the de 200 m distance competition[3]. Finally, they have been higher than in high level Australian female athletes (44.8 ± 6.0 ml/kg/min), studied by Bishop[1]. It is worth highlighting that in all mentioned studies, the athletes have been evaluated in ergometer-kayak, which potentially offer them advantage compared with the canoers from this study due to specificity of the movements. In the movements performed in cycle ergometer for upper extremities, the chest, back and abdomen muscles are as intensely required as in the simulation of the canoeing gestures.

Significant correlations between several methodologies for estimation of metabolic and threshold transitions, $\dot{V}O_2$peak and performance in velocity canoeing and in longer events have been reported by other authors. Fry and Morton[2], for instance, showed significant correlations between LV_1 and performance in 500 to 42.000 m events (r = –0.48 to –0.72). Similar values were found between the $\dot{V}O_2$peak expressed in absolute terms and the times in the mentioned distances (r = –0.56 to –0.80). Similar results were found by Bishop[1] concerning performance in 500 m of female athletes. Interestingly, these aerobic variables roughly explain the performance in 200 m, being it the best one predicted by variables obtained in anaerobic tests[3]. Functions concerned with instantaneous muscular strength and muscular work in 60 s tests also seem to be able to predict performance in distances between 500 and 42.000 m[2].

We believe that the lack of significance in the correlations between measurements concerning body weight of LV_1, LV_2 and $\dot{V}O_2$peak, and performance, is due to the fact that in canoeing the negative effect of the body weight over dislocation is attenuated by the fact that the boat is hold on the water surface. In this situation, the absolute capacity of oxygen uptake and utilization, both in the thresholds and maximal effort, seem to be more relevant.

In the distances investigated in this study, there is probably an integrated participation of the anaerobic capacity and aerobic power, with the influence of the former in the 200 m, of both in the 500 m, and probably higher of the latter in the 1.000 m. despite the aerobic predominance in the 1.000 m, in this distance, the main limiting factor must be the capacity of standing high levels of muscular lactate, since in this stage, one works close to the $\dot{V}O_2$peak, consequently above the LV_2, what would cause a progressive increase of the lactate concentrations, and consequent fatigue caused by the deletereal effects of the pH decrease in the contractile apparatus.

A limitation of the present study has to do with the lack of other physiological (anaerobic capacity, strength), as well as anthropometric measurements, which could be obtained in laboratory with the aim to improve performance predictions in velocity canoeing, for samples similar to the one analyzed in this work. Such fact would aid in the proposition of more complex prediction equations, with multiple entrance variables. The correlations presented in this study between LV_2 and $\dot{V}O_2$peak, and performance, do not allow that these indicators are used as exclusive time determinants in velocity canoeing events. Therefore, further investigations which include other prediction variables as well as analysis of the measurements sensitivity to the longitudinal effects of training are needed.

CONCLUSIONS

It is concluded that the aerobic function indicators obtained in cycle ergometer of upper extremities may predict performance in canoeing velocity events. The LV_2 presented correlation of –0.685 with performance in 1.000 m, and the $\dot{V}O_2$peak correlated both with performance in 500 m ($rs = -0.699$) and in 1.000 ($rs = -0.734$). Therefore, both constitute physiological indicators which may be potentially applied in evaluation of canoers. It is worth mentioning that the measurements concerned with body weight did not present the same predictive properties.

All the authors declared there is not any potential conflict of interests regarding this article.

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