Comparison of absolute and relative phisiological responses of cyclists and triathletes

Fernando Diefenthaeler[1], Cláudia Tarragô Candotti[1,2], Jerri Ribeiro[1] and Álvaro Reischak de Oliveira[1]

ABSTRACT

Bases and objective: The ventilatory threshold (VT) has been used as an indicator of the lactate threshold and used as a reference for endurance training. The purpose of this study was to compare the maximal oxygen uptake ($\dot{V}O_{2MAX}$) and the VT during a bicycle ergometer test between cyclists and triathletes. **Methods:** $\dot{V}O_{2MAX}$ was determined by open-circuit spirometry in 12 cyclists and 13 triathletes. The ventilatory equivalent for oxygen consumption, the ventilatory equivalent for carbon dioxide production, partial pressure of oxygen and the partial pressure of carbon dioxide ($P_{ET}CO_2$) were plotted in function of the workload. The criterion to determinate the VT was when the ventilatories equivalents increased with a concomitant reduction in the $P_{ET}CO_2$. **Results and conclusions:** There was difference ($p < 0.05$) for the $\dot{V}O_{2MAX}$ (57.72 ± 3.92 and 49.47 ± 5.96 kg·ml^{-1}·min^{-1}), $\dot{V}O_2$ at VT (46,91 ± 5,96 and 42,16 ± 4,97 kg·ml^{-1}·min^{-1}), and maximal heart rate (FC_{MAX}) (188.83 ± 12.89 and 174.61 ± 13.79 bpm) between cyclists and triathletes, respectively. Therefore, there was no difference for the %$\dot{V}O_{2MAX}$ (81.42 ± 7.61 and 85.18 ± 6.87%), the heart rate at VT (168.5 ± 13.79 and 157.23 ± 16.15 bpm), as well as for the %FC_{MAX} at which VT occurred in these athletes (89.23 ± 6.98 and 90.05 ± 1.04%). In conclusion, cyclists and triathletes showed different aerobic capacity because they had unlike physiological adaptations.

Keywords: Ventilatory threshold. Maximal oxygen uptake. Heart rate.

INTRODUCTION

Cycling is one of the most traditional sports in the world, especially in Europe, where it is considered the number one sport. This sport dates back from the XIX century, when the first competition bicycles as well as the first events appeared, being the *Tour de France* the most traditional one. Training in cycling is based on the athlete's trial to go beyond his limits in events which extend for 23 days, in many different kinds of terrain. Such fact causes an important demand of the several physiological, biochemical and biomechanical aspects. Therefore, the control of all these variables is extremely important so that the athletes' performance is optimized[1].

Triathlon is a sport which involves swimming, cycling and running and represents a new approach of these three modalities concerning training, gear, regulation and competition[2-4]. The athletes who dedicate themselves to this modality should be polyvalent and present versatility in order to equally move in the three sports. Training in triathlon since it is a mixed event (swimming, cycling and running), usually results in adaptations which improve the oxygen maximal uptake values ($\dot{V}O_{2MAX}$), as well as adaptations in the anaerobic threshold.

Training in triathlon therefore, involves the three modalities simultaneously, and this fact implies in a reduction in the training time of the athlete for each specific sport, when compared with an athlete who only practices one modality[5]. However, it has been reported that the aerobic maximal capacity use of each modality suggests a generalized improvement in the cardiovascular system; that is, it seems that specific training of a modality intervenes in the other[6]. Therefore, it is believed that the success in an extended triathlon event (*Ironman*) may be assumed by the result of the athlete's ability to keep a strong rhythm in the three modalities for an extended period of time.

The anaerobic threshold has been successfully used as a performance parameter in aerobic endurance sports[7] being defined as the highest metabolic rate where the blood lactate concentration is kept at a same level (*steady-state*), during an extended exercise[8]. The anaerobic threshold can be determined from the ventilatory method[9], and has been proposed as a capacity index for extended exercises and also as a reference for training prescription[7-8,10].

Some studies have measured the $\dot{V}O_{2MAX}$ through the analysis of the expired gases or even by measuring the blood lactate concentration in order to detect the anaerobic threshold in athletes who practice only one modality[6-7]. Elite cycling and running athletes usually present high $\dot{V}O_{2MAX}$ and anaerobic thresholds when evaluated in their respective specialties (cycle ergometer and treadmill). As the triathletes are not specialized in any of the three modalities which compose the triathlon training, it is believed that they must present behavior distinct from swimmers, cyclists and runners, both for the $\dot{V}O_{2MAX}$ and anaerobic threshold.

Considering that the cycling step represents more than 50% of the total time of a triathlon event and it precedes running, a step which has been referred as decisive in the event[6], it seems to be important that the triathlete presents performance in cycling close to that presented by elite cyclists.

Last decade, the average time of a 40 km against-clock event in cycling was of approximately 48 min[11-12], while in triathlon it was 54 min (*International Triathlon Union*). Nowadays, due to changes in the triathlon regulations, the time of the cycling step has presented a significant reduction. Once the decrease of the difference between triathletes' performance and cyclists is observed, the determination of the physiological differences between the two groups is of extreme importance. Studies which search this comparison are going to significantly contribute to the determination of new training strategies, since the cyclist's performance must be used as a reference parameter for the triathlete's training prescription.

Therefore, the aim of the present study was to compare the $\dot{V}O_{2MAX}$ and the $\dot{V}O_2$ corresponding to the ventilatory threshold (VT) of cyclists and triathletes during a test in cycle ergometer. As hypothesis of this study, it was considered that both (1) $\dot{V}O_2$ corre-

1. Laboratório de Pesquisa do Exercício – LAPEX – UFRGS, Porto Alegre, RS.
2. Curso de Educação Física – UNISINOS, São Leopoldo, RS.

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Correspondence to: Escola de Educação Física, Universidade Federal do Rio Grande do Sul – LAPEX – Sala 212, Rua Felizardo, 750, Bairro Jardim Botânico – 90690-200 – Porto Alegre, RS.
E-mail: fdiefenthaeler@gmail.com / aroliveira@esef.ufrgs.br / candotti@unisinos.br

sponding to the ventilatory threshold (VT) and (2) percentage of the maximal oxygen uptake (%$\dot{V}O_{2MAX}$) of cyclists are higher than the triathletes', once the triathlete practices two extra sports modalities besides cycling, and therefore is not able to become a specialist.

METHODOLOGY

Sample

The sample consisted of 12 cycling athletes (group 1) and 13 triathlon athletes (group 2), both elite groups, with a minimum of three years of practice of the respective modalities. All individuals were male. There was no age restriction. Prior to the test, detailed information about the procedures to be used was provided. All individuals signed a free and clarified consent form. This study was approved by the Ethics Committee of the Federal University of Rio Grande do Sul.

Acquisition procedures

The athletes were submitted to a protocol for determination of $\dot{V}O_{2MAX}$. Such protocol was performed in a *CARDIO$_2$* computerized cycle ergometer (*Medical Graphics Corp.,* St Louis, USA), which provides the work load of each step as well as the pedaling cadence. The $\dot{V}O_{2MAX}$ was directly measured, using a gas analyzer model CPX/D (*Medical Graphics Corp.,* St Louis, USA).

The used protocol was the one in a ramp with load increments of 30 watts·min^{-1} until exhaustion or when the athletes could not keep the cadence above 70 rpm. After the test end, an active recovery in the bicycle, pedaling for four minutes was suggested to the athletes.

The athletes were positioned in the cycle ergometer, remaining two minutes at rest for registration of basal values (when the respiratory coefficient was around 0.8 the test was initiated). During the protocol, the athletes kept a cadence above 90 rpm. The heart rate was monitored during the entire protocol through an electrocardiogram at CM5 derivation (Funbec, Brazil).

The original seat and pedals of the cycle ergometer were substituted for equipments used in competition bicycles, which enabled the athletes to use their own slippers.

Analysis procedures

Once the $\dot{V}O_{2MAX,}$ the carbone dioxide production ventilatory ($\dot{V}CO_2$) and the equivalent ventilation (EV) provided by the ergospirometer were known, these values were plotted in a chart in relation to the test's load. The $\dot{V}O_2$ value considered maximum was the highest value kept for 30 consecutive seconds during the test[10].

The oxygen equivalent ventilatory (VE/$\dot{V}O_2$), the CO_2 equivalent ventilatory (VE/$\dot{V}CO_2$), the oxygen expired pressure ($P_{EP}O_2$) and the CO_2 expired pressure ($P_{EP}CO_2$) were plotted in charts, in relation to the load. The $\dot{V}O_2$ corresponding to the second ventilatory threshold was determined as being the point of increase of the two ventilatory equivalents concomitant with the reduction of the $P_{ET}CO_2$ and with the second increase of the ventilatory curve. The double-blind strategy through the evaluation of the charts conducted by two specialists was used in order to determine this value.

Statistical treatment

The statistical analysis was performed by the SPSS 10.0 software. The t-independent test was used in order to verify the differences between triathletes and cyclists concerning: (1) $\dot{V}O_{2MAX}$, (2) VT and (3) %$\dot{V}O_{2MAX}$. The significance level adopted was 0.05.

RESULTS AND DISCUSSION

The outcomes of this study demonstrated that there was difference ($p < 0.05$) for the maximal oxygen uptake ($\dot{V}O_{2MAX}$) and for the ventilatory threshold (VT) between groups 1 and 2, of cyclists and triathletes, respectively, according to figure 1. The outcomes also demonstrated that there was no difference between the cyclists and the triathletes for the percentage of the maximal oxygen uptake (%$\dot{V}O_{2MAX}$).

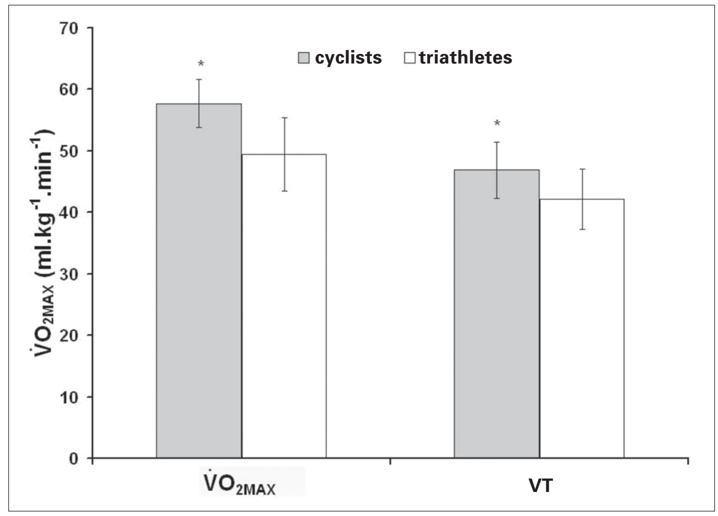

Figure 1 *– Means and standard deviations of the maximal oxygen uptake ($\dot{V}O_2$ MAX) as well as the $\dot{V}O_2$ corresponding to the ventilatory threshold (VT) of cyclists and triathletes. * $p < 0.05$.*

The mean values of the $\dot{V}O_{2MAX}$ and VT were different, showing that both groups did not have the same aerobic training level. The triathletes presented the $\dot{V}O_{2MAX}$ means (49.47 ± 5.96 kg·ml^{-1}·min^{-1}) as well as $\dot{V}O_2$ in the VT (42.16 ± 4.97 kg·ml^{-1}·min^{-1}) lower than the cyclists' (57.72 ± 3.92 kg·ml^{-1}·min^{-1} and 46.91 ± 5.96 kg·ml^{-1}·min^{-1}), respectively, showing that the specialized training of cyclists allowed physiological adaptations which resulted in greater aerobic capacity for them, when compared with the triathletes. However, the percentage mean of the maximal oxygen uptake (%$\dot{V}O_{2MAX}$), which represents how much the VT is close to the $\dot{V}O_{2MAX}$ of the triathletes (85.18 ± 6.87%) was slightly higher than the cyclists' (81.42 ± 7.61%). The explanation would be that the triathletes group despite not specifically practicing cycling, splits its time training in two modalities (swimming and running), which demands a higher number of weekly hours for its training than the cyclists group.

I a study using cycle ergometer and treadmill it was observed that the majority of triathletes registered higher values of $\dot{V}O_{2MAX}$ in running, followed by cycling and swimming. The majority of elite triathletes obtained $\dot{V}O_{2MAX}$ values close to or lower than the $\dot{V}O_{2MAX}$ of elite cyclists and runners[13]. Thus, these data corroborate that the results found in the present study are according to the literature.

Blood lactate and ventilatory threshold have been used in order to verify the point where a dramatic increase in lactic acid production occurs (metabolic acidosis) during exercise[14]. The magnitude of the fractional usage of the maximal oxygen uptake (%$\dot{V}O_{2MAX}$), concerning the anaerobic threshold, seems to be much closer to the one reported in performance during aerobic endurance events in running and cycling[15-17].

Such correlation can be explained by the fact that during the test in cycle ergometer, the applied load, the velocity, the cadence of the pedaling as well as the heart rate (HR) at each moment of the test can be measured. Therefore, when the moment in which the ventilatory threshold and the $\dot{V}O_{2MAX}$ occurred is verified, one may relate such values with the velocity, the load, the HR and the cadence in the respective points, allowing hence, the training optimization. The results obtained in laboratory tests can be used in the prescription of a more efficient training, as well as in the planning of competition strategies.

The ventilatory threshold and lactate reported during a study with triathletes[7], were similar or a little lower than the ones reported in cycling athletes. According to Ribeiro *et al.*[10], factors associated with the anaerobic threshold limit the use of the $\%\dot{V}O_{2MAX}$ which can be sustained during aerobic endurance exercises. In cyclists with similar values of $\dot{V}O_{2MAX}$, the fatigue time was more than double for those athletes in which the threshold occurred at 81% of the $\dot{V}O_{2MAX}$ when compared with those in which the threshold occurred at 66% of the $\dot{V}O_{2MAX}$. It means that the higher the $\dot{V}O_{2MAX}$ percentage, the more efficient the athlete will be, since he will be able to support and keep a rhythm much closer to his maximum for a long period of time, with no increase in the blood lactate production.

In the present study, the cyclists and the triathletes presented difference ($p < 0.05$) in the $\dot{V}O_2$ value corresponding to the ventilatory threshold. Thus, the first hypothesis was accepted, since group 1 presented higher values of VT than group 2, showing that the training specificity altered the physiological adaptations. Nonetheless, the analysis of the percentage of the maximal oxygen uptake ($\%\dot{V}O_{2MAX}$) did not present difference between groups. Therefore, the second hypothesis of this study was discarded.

$\dot{V}O_{2MAX}$ is considered the best indicator of aerobic capacity and VT is considered the indicator most sensitive to the aerobic conditioning alterations in response to training[18-19]. However, some researchers have recently verified that the $\dot{V}O_{2MAX}$ is not the best indicator for performance in aerobic endurance events[1,14]. It has been suggested that the most important is the rhythm which the athlete is able to keep with no accumulation of great amounts of lactate (approximately 5% below the VT). There seems to be a consensus that the increase in blood lactate during intense exercise is a limiting factor for performance, especially in aerobic endurance events[1,10,14-16].

The outcomes of the present study concerning $\dot{V}O_{2MAX}$, VT and $\%\dot{V}O_{2MAX}$ obtained for both groups, suggest that regardless the training specificity, the amount of training hours (sessions) and the training intensity must be the determinant factors for the cyclists and triathletes to present distinct levels of aerobic fitness.

Since triathlon was included in the Olympic Games (Olympic Games of Sydney, 2000), the technical level in each modality which composes the sport required from the athletes an extremely high level of physical fitness. In the search for the best performance possible, triathletes and coaches have used as parameters for training prescription, individual times of swimming, cycling and running athletes.

Therefore, we believe that, as the group of triathletes uses the $\dot{V}O_{2MAX}$ and $\dot{V}O_2$ values corresponding to the VT reached by the cyclists group as reference in a trial to improve their aerobic capacity, an improvement in performance in the cycling step, as well as a better final performance during a triathlon event will be surely observed.

The outcomes of this study have also demonstrated that there was a difference ($p < 0.05$) for the maximal heart rate (HR_{MAX}) between groups 1 and 2, being the highest values for the cyclists. The outcomes also demonstrated that there was no difference for the heart rate corresponding to the ventilatory threshold (HR_{THRE}) and for the percentage of the maximal heart rate ($\%FC_{MAX}$) between cyclists and triathletes. Figure 2 illustrates the means and standard deviations of the HR_{MAX} and HR_{THRE} in both groups.

The HR_{MAX} mean of the cyclists (188.83 ± 12.89 bpm) was higher than the triathletes' (174.61 ± 13.79 bpm) suggesting that the cyclists group, due to the training specificity can reach higher peak values. The cyclists have a heart rate zone during intense exercise very close to their estimated maximal threshold (220 – age).

Regardless the kind of training, the physiological variables ($\dot{V}O_{2MAX}$ and HR_{MAX}), of both groups presented higher mean values for the cyclists, probably due to the training specificity and not the training load, which is according to other studies[15]. Cyclists perform an average of ten weekly training sessions, split in two shifts (morning and afternoon), while triathletes perform an average of 13 training sessions split in: swimming (five sessions), cycling (four sessions) and running (four sessions).

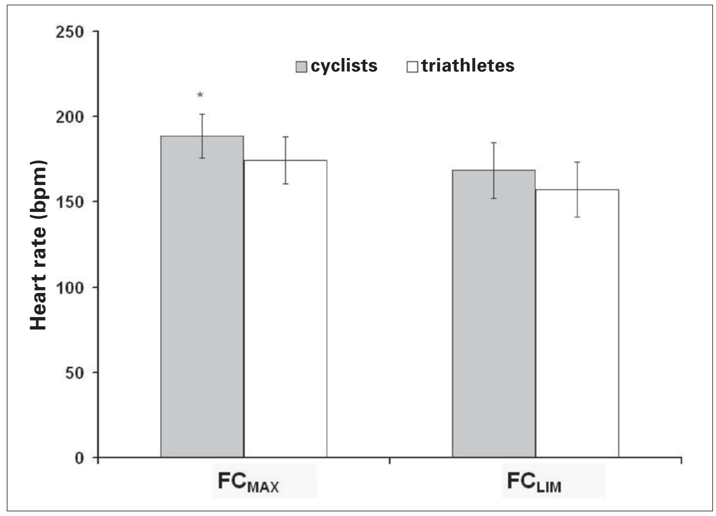

Figure 2 *– Means and Standard deviations of the maximal heart rate (HR_{MAX}) as well as heart rate threshold (HR_{THRE}) of cyclists and triathletes. * $p < 0.05$.*

In the majority of times, the training is performed in conditions which do not allow exact control of the same velocity which was obtained in the tests. Thus, the heart rate corresponding to this velocity is used. Therefore, an easier way to control the effort intensity is obtained, once the HR control at small time intervals is much simpler and practical and widely used.

According to Denadai[20] and Morton and Billat[21], there is no need to control velocity, once it is presumed that the velocity versus HR ratio does not change during the training session. The authors' claim can be contested, since the velocity versus HR ratio is not always steady. For instance, in a cycling training, the HR becomes a constant steady and reliable when compared with velocity, since many times the site (trajectory terrain) has ups and downs and wind against or for, which cause pedaling to constantly change, with no change in the exercise intensity, though.

In a study involving cyclists[20], six subjects performed three tests in an electromagnetic bicycle, with load increments of 25 W at every 3 min. The first test was for anaerobic threshold setting (AT), the second with load immediately below the AT and the third with load immediately above the AT. In his conclusion, the author states that the HR in both exercises performed below and above the AT do not serve as a suitable index for intensity control of continuous exercise, since as time passes by (> 10 min) there is a dissociation between HR and the overload which has been applied, determining thus, a lower adaptation of the body in response to training. He also concluded that the prescription of the intensity of the continuous exercise should be done from the existing methodologies ($\%HR_{MAX}$, $\%\dot{V}O_{2MAX}$ or AT) and that the training session control should be, whenever possible, based on the overload found ($km \cdot h^{-1}$, $m \cdot min^{-1}$ or Watts).

The moment in which a dissociation between HR and the imposed work load occurs, it is presumed that the muscles begin a fatigue process, with possible increase in lactic acid production with the purpose to keep the same intensity. Therefore, the HR tends to increase in order to compensate for the adaptations required during the exercise.

The percentage of the maximal heart rate ($\%HR_{MAX}$) has been extensively used as prescription means of exercise intensity. Such fact occurs due to the great easiness in its measurement as well as to its close relationship with the oxygen uptake, and consequently, with exercise intensity. After analysis of the obtained results in the present study, in which cyclists and triathletes presented very similar $\%HR_{MAX}$, it is suggested that both groups should train using the $\%HR_{MAX}$ as an intensity modulator[20].

Having results of the present study as reference, it is believed that the training intensity prescription of both groups can be easily modulated by the percentage of the maximal oxygen uptake ($\%\dot{V}O_{2MAX}$) and, in this group of individuals, by the percentage of the maximal heart rate frequency ($\%HR_{MAX}$), although significant difference has not been found for the $\%HR_{MAX}$ between cyclists and triathletes. The outcomes show that both cyclists and triathletes will be working close to their ventilatory thresholds.

CONCLUSIONS

The outcomes of this study demonstrated that both cyclists and triathletes presented different values for ventilatory thresholds. However, they also suggest that the athletes of both modalities do not train at the same effort intensity, so that the physiological adaptations for each group of athletes are distinct. It would be interesting to conduct further investigation with a larger sample as well as to use national elite cyclists and triathletes in order to compare and standardize these results. It is believed that having this comparison with cyclists and triathletes as a starting point, they will be able to be classified according to their performance in the test in cycle ergometer.

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REFERENCES

1. Burke ER. Physiology of cycling. In: Garrent & Kirkendall, editors. Exercise and sport science. Philadelphia: Lippincott Williams & Wilkins, 2000. p. 759-70.
2. O'Toole ML, Douglas PS, Hiller WD. Applied physiology of a triathlon. Sports Med. 1989;8(4):201-25.
3. Filho LAD. Triatlo. Rio de Janeiro: Editora Sprint; 1995.
4. Margaritis I. Factors limiting performance in the triathlon. Can J Appl Physiol. 1996;21(1):1-15.
5. Roalstad MS. Physiology testing of the ultraendurance triathlete. Med Sci Sports Exerc. 1989;21(5):200-4.
6. Galy O, Manetta J, Coste O, Maimoun L, Chamari K, Hue O. Maximal oxygen uptake and power of lower limbs during a competitive season in triathletes. Scand J Med Sci Sports. 2003;13:185-93.
7. Schneider DA, Lacroix KA, Atkison GR, Troped PJ, Pollack J. Ventilatory threshold and maximal oxygen uptake during cycling and running in triathletes. Med Sci Sports Exerc. 1990;22(2):257-64.
8. McLellan TM, Cheung KSY. A comparative evaluation of the individual anaerobic threshold and the critical power. Med Sci Sports Exerc. 1992;24(5):543-50.
9. Wasserman K, MB McIlroy. Detecting the threshold of anaerobic metabolism in cardiac patients during exercise. Am J Cardiol. 1964;14:844-52.
10. Ribeiro JP, Yang J, Adams RP, Kuca B, Knutten HG. Effect of different incremental exercise protocols on the determination of lactate and ventilatory thresholds. Braz J Med Biol Res. 1986;19:109-17.
11. Lucía A, Hoyos J, Chicharro JL. Physiology of professional road cycling. Sports Med. 2001;31(5):325-37.
12. Mujika I, Padilha S. Physiological and performance characteristics of male professional road cyclists. Sports Med. 2001;31(7):479-87.
13. Rowlands DS, Downey B. Physiology of triathlon. In: Garrent & Kirkendall, editors. Exercise and sport science. Philadelphia: Lippincott Williams & Wilkins, 2000. p. 919-39.
14. La Fontaine TP, Londeree BR, Spath WK. The maximal steady state versus selected running events. Med Sci Sports Exerc. 1981;13(3):190-2.
15. Ekkekakis P, Hall EE, Petruzzello SJ. Practical markers of the transition from aerobic to anaerobic metabolism during exercise: rationale and a case for affect-based exercise prescription. Prev Med. 2004;38:149-59.
16. Hug F, Bendahan D, Le Fur Y, Cozzone PJ, Grelot L. Metabolic recovery in professional road cyclists: A 31P-MRS Study. Med Sci Sports Exerc. 2005;37(5): 846-52.
17. Coyle EF, Coggan AR, Hopper MK, Walters TJ. Determinants of endurance in well-trained cyclists. J Appl Physiol. 1988;64(6):2622-30.
18. Edwards AM, Clark N, Macfadyen AM. Lactate and ventilatory thresholds reflect the training status of professional soccer players where maximum aerobic power is unchanged. J Sports Sci Med. 2003;2:23-9.
19. Hebestreit H, Staschen B, Hebestreit A. Ventilatory threshold: a useful method to determine aerobic fitness in children? Med Sci Sports Exerc. 2000;32:1964-9.
20. Denadai BS. Limiar anaeróbio: considerações fisiológicas e metodológicas. Revista Brasileira de Atividade Física e Saúde. 1995;2(1):74-88.
21. Morton RH, Billat V. Maximal endurance time at $\dot{V}O_{2MAX}$. Med Sci Sports Exerc. 2000;32(8):1496-504.