79 - BLOOD LACTATE LEVELS DURING CONTINUOUS EXERCISE WITH STABLE HEART RATE DETERMINED FROM CONCONI TEST

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INTRODUCTION

The identification and physiological explanation of a metabolical situation in which an inbalance between lactate production and elimination causing its accumulation in muscle and blood is one of the most investigated and controversial subjects in exercise physiology today (SKINNER & McLELLAN, 1980; CONCONI et al.,1982; BROOKS, 1985; DAVIS, 1985; HECK et al., 1985; MADER & HECK, 1986; CONCONI et al., 1996; JONES & DOUST, 1997; BODNER & RHODES, 2000). The anaerobic threshold (AnT) has been used in the evaluation and prescription of exercises for athletes and sedentary people, but terminology and methods of its detection may vary (CONCONI et al., 1982; LONDEREE, 1986; NOAKES, 1988; COYLE et al., 1988; DENADAI, 1995; VACHON et al., 1999).

The blood lactate concentration after which it constantly accumulates after 4,0 mmol/l is called anaerobic threshold (HECK et al., 1985; BOULAY et al., 1997).

CONCONI et al. (1982) proposed a method to estimate the AnT using the relationship between heart rate (HR) and exercise intensity. In a preliminary study (CONCONI et al. 1982), middle and long distance runners were evaluated. In these tests, the relationship between running speed and HR was linear in low and moderated running velocities, but assumed a curved pattern in running velocities near maximal. For the authors, there was a strong relationship between the running velocity at the break-point of the HR (HRDP) and the AnT. They suggested that the alterations of a linear pattern of HR/running velocity could, at least partially, be explained by a more intense participation of anaerobic energy generation.

The Conconi test has been used by coaches to evaluate the aerobic capacity of their athletes and for training prescription. Many studies investigated the validity of Conconi's test in different sports with contradictory results (KUIPERS et al., 1988; ZACHAROGIANNIS & FARRALLY, 1993; HOFMANN et al., 1994; BUNC et al. 1995; JONES & DOUST, 1995; CONCONI et al., 1996; JONES & DOUST, 1997; VACHON et al., 1999). Correlation coefficients that vary from very low to very high were found between HRDP and ventilatory or lactate thresholds (KUIPERS et al., 1988; ZACHAROGIANNIS & FARRALY, 1993; BUNC et al., 1995; VACHON et al., 1999). However, only a few studies investigated the physiological responses during continuous exercise at a constant intensity which corresponded to the HRDP on the cycle-ergometer (POKAN et al., 1993; HOFMANN et al., 1994).

METHODS

Subjects

This investigation was previously approved by the Ethical Research Committee of the Universidade Federal de Minas Gerais. Eight male subjects were studied. They were trained cyclists, considered healthy according to the PAR-Q questionnaire (ACSM, 1995), non-smokers, showed a maximal oxygen consumption of at least 50 $ml.kg^{-1}.min^{-1}$, and were between 19 and 30 years old. Subjects gave their informed consent to participation after having received all explanations concerning the methods to be used.

After measurement of anthropometrical data (body mass, body height and skinfolds to estimate percent body fat), subjects undertook a maximal progressive exercise protocol on cycle-ergometer to estimate maximal oxygen consumption (ACSM, 1995).

Tests were done on afternoon in an environmental chamber (RUSSELS modelo WMD-1150-5), which was set for a thermoneutral environment (22° C e 60% relative humidity). The subjects were exposed to the thermoneutral environment at rest in a sitting position during 15 minutes prior to all exercise situations. Rest data was then collected.

Exercise protocols

An adapted Conconi protocol proposed by SZMUCHROWSKI (1995) and SZMUCHROWSKI et al. (1999) was used to detect the HRDP. This protocol is characterized by an increase of exercise intensity using a progressive pedal cadence at each intensity level with a constant pedal resistance. HR was measured (Polar Vantage XLTM) at the end of each intensity level and HRDP was determined using a regression coefficient. Pedal frequency was controlled by the subjects using an audio record and visually using a pedal frequency monitor (Polar X-Trainer). A warm-up exercise bout pedaling during 4 minutes at 60 rpm and 1 additional minute pedaling at 45 rpm was done using 50 % of the pedal resistance to be used during the test (the load used during the adapted Conconi test was 50% of the last achieved load during the progressive maximal exercise for estimation of maximal oxygen consumption).

Exercise intensity increased progressively due to the elevation of pedal frequency, beginning with 45 rpm and increasing by 5 rpm at every 100 pedal cycles, until exhaustion. Each intensity level corresponded to a cycled distance of 600 meters. Test was interrupted when the subjects were not able to sustain the pedal frequency determined. HRDP was then calculated using a regression's equation for a specific Conconi's test tool of the Polar Advantage software. Only the tests in which the HRDP was identified were considered.

One week after the adapted Conconi test, subjects were submitted to a continuous exercise with stable HR (exeHR) during 45 minutes. Subjects were told to maintain HR within a range of 5 bpm corresponding to the HR on HRDP minus 5 bpm, using the same pedal resistance of the Conconi test. During the exeHR, HR and power production were continuously measured and registered every minute. Blood lactate concentrations were determined on minutes 5, 15, 25, 35 and 45. In case of exhaustion before the 45 minutes, variables were measured at time of exercised cessation. Blood samples were taken from the finger tip using a sterilized steel lancet and analyzed with a specific photometer for lactate (Accusport, Boehringer, Germany). Lactate threshold was defined as the moment during exercise in which lactate levels increase to concentrations equal or higher than 4 mmol/l (HECK et al., 1985) for comparison with the measured lactate concentrations. Produced relative power ($W.kg^{-1}$) was measured using a specific software MCE (Multi Cycle Ergometer, version 2.3, Poland) installed in a personal computer, which was connected to the cycle-ergometer.

Student's t-test was used to analyze differences between lactate concentrations measured during the 45 minutes of continuous exercise and the 4 mmol/l level. Significance level was set at $p<0,05$.

RESULTS

Anthropometrical characteristics and estimated VO_2max are presented on table 1.

The HRDP was found in seven of the eight subjects submitted to the adapted Conconi test. For this reason, only seven subjects participated on exeHR. All these subjects were then able to carry out the exercise with constant HR calculated

form the HRDP during the adapted Conconi test, maintaining it stable within the range comprehending the HRDP minus 5 bpm.

Table 1- **Anthropometric characteristics and aerobic capacity.**

	Age (years)	Body mass (kg)	Body height (cm)	Perc. Fat (%)	VO_2 max ($ml.kg^{-1}.min^{-1}$)
V1	30	66,95	169,00	15,22	61,24
V2	20	67,18	169,50	11,22	56,56
V3	20	62,68	170,00	10,93	60,63
V4	24	58,16	168,50	10,07	75,65
V5	19	62,78	171,50	6,22	65,31
V6	21	52,85	167,00	5,98	66,23
V7	30	70,23	177,00	11,12	58,38
V8	22	66,16	183,00	7,60	66,51
mean	23,25	64,08	170,17	9,80	63,81
stand. dev.	4,43	5,18	3,50	3,09	6,03
vc	0,19	0,08	0,20	0,32	0,09

Mean,standard deviation (stand. dev.) and variation coefficient (VC).

Mean HR on HRDP was 168,5 ± 6,9 bpm, corresponding to 89,6% of HRmax (188,14 ± 4,63).

Table 2 shows the lactate concentrations measured during exeHR for each subject and the mean concentrations for the different moments in which blood samples were taken. Mean values are compared to the level of 4 mmol/l. Significant differences are shown on table (*, p<0,05).

Table 2 – **Lactate concentrations during exeHR (mmol/l)**

	V1	V2	V3	V4	V5	V6	V7	mean ± s
Rest	3,00	2,55	2,00	2,80	2,75	1,80	2,15	2,44 ± 0,45
5'	4,20	6,90	4,15	6,95	5,05	4,65	6,70	5,51* ± 1,29
15'	4,20	5,75	3,95	6,45	4,10	4,60	5,30	4,91* ± 0,95
25'	3,15	6,00	4,45	5,00	3,95	4,05	4,40	4,43 ± 0,89
35'	4,90	5,05	3,85	4,95	3,85	3,65	3,70	4,28 ± 0,65
45'	2,95	5,15	3,90	4,35	3,80	3,20	3,30	3,81 ± 0,76

Individual values and mean ± standard deviation (s) dos níveis de lactato sangüíneo (mmol/l).
* Significantly different (p < 0,05) from 4,0 mmol/l.

Significant differences between measured lactate concentrations and the value of 4 mmol/l were observed only on minutes 5 and 15.

DISCUSSION

In the present investigation, only in one of the subjects submitted to the adapted Conconi test the HRDP was not identified. The same success on identifying the HRDP was achieved in the studies of CONCONI et al. (1982); MAFFULLI et al. (1987); HOFMANN et al. (1994); BUNC et al. (1995); CONCONI et al. (1996); VACHON et al. (1999), where the HRDP was identified in all or almost all subjects.

From the seven subjects who showed a HRDP, all were able to maintain the HR within the range determined during exeHR, with small variations from the average. The mean HR on HRDP was 168,5 ± 6,9 bpm, corresponding to 89,6% of the mean maximal HR (188,14 ± 4,63). HOFMANN et al. (1994) found a similar percent value of the maximal HR (90,2 ± 3,0%). SWENSEN et al. (1999), when determining the HR on maximal lactate steady state of ten trained cyclists, registered an average HR (167 ± 9,5 bpm) that was very similar to the HR observed in the present study.

To achieve the HR determined by the HRDP during the exeHR, the subjects had to produce high power levels during the first minutes of exercise. This may explain the high lactate concentrations observed on minutes 5 and 15 that were significantly different from the lactate threshold concentrations assumed in the present study (4 mmol/l). From this moment on the lactate concentrations were remained stable and not different from 4 mmol/l.

This is accordance with the observations of BOULAY et al. (1997), which submitted 15 male subjects to a continuous exercise during 90 minutes on a cycle-ergometer at a HR which corresponded to the HR on the ventilatory threshold previously determined minus 5 bpm. On minutes 10, 20 and 30 the authors observed lactate concentrations significantly higher than that corresponding to the ventilatory threshold (3,91 ± 0,25 mmol/l). According to the authors, this was due to the extra power needed to achieve the determined HR. On minutes 40 and 50, the lactate concentrations did not differ from those observed on the ventilatory threshold. These results indicate that the previously determined HR during the continuous exercise may be sustained for a long period in trained and sedentary subjects, the authors state. HOFMANN et al. (1994) used an adapted Conconi test on cycle-ergometer to identify the HRDP in seven women, students of Physical Education. They detected the HRDP in all subjects. The test began with 40 watts, and the load was increased by 10 watts every minute. Later, subjects carried-out 2 different tests during 20 minutes each, with a workload corresponding to 10% higher and 10% lower than the work load previously determined as the load on HRDP. All the subjects were able to complete the test with the work load lower than that on HRDP. HR, oxygen consumption and lactate increased significantly during the first 5 minutes of exercise but remained stable further. Subjects showed lactate concentrations that were close but lower than 4 mmol/l during the 20 minutes of exercise. Only HR increased significantly between minutes 10 and 15. According to the authors, these results confirm the validity of the Conconi test.

Contrary to the observed in the present study, JONES & DOUST (1997) detected the HRDP in only 9 of 14 subjects (trained runners) tested with the Conconi in a laboratory situation. Only one subject was able to run continuously for 30 minutes on a treadmill in a velocity 0,5 km/h lower than the running velocity corresponding to the HRDP. In average, the subjects could maintain the exercise intensity for only 15,9 ± 6,7 minutes, reaching lactate concentrations of 8,1 ± 1,8 mmol/l. KUIPERS et al. (1988) evaluated the anaerobic threshold of athletes and sedentary individuals on the cycle-ergometer with load increases of 10 watts every 45 seconds until exhaustion. He also measured the work load that each subject was able to maintain at blood lactate concentrations of 4,0 mmol/l in stable conditions for 5 minutes. The HRDP was detected in only 6 of 13 subjects tested and the work load at the HRDP was significantly higher (p<0,05) than the work load corresponding to the lactate concentration of 4 mmol/l, in stable conditions. The author concluded that, in cyclists the HRDP does not necessarily occur and, if it occurs, the work load does not correspond to that observed in stable conditions. Differences between exercise protocols used in

many studies may explain the contrary results observed. In the present study, HRDP was determined using the software Polar Advantage, while in JONES & DOUST (1997), HRDP was determined subjectively by two experienced researchers. Furthermore, in the present study we used the protocols initially proposed by CONCONI et al. (1982), that means, progressive increases in cycling frequency and, therefore reduced duration of intensity stages, on the contrary of KUIPERS et al. (1988).

In this investigation, the HRDP, calculated with the Conconi method, allowed the determination of an exercise intensity in which blood lactate concentrations remained stable and not significantly different from 4,0 mmol/l between minutes 25 and 45. The results suggest that the Conconi test may be used to estimate the lactate anaerobic threshold of 4,0 mmol/l.

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BLOOD LACTATE LEVELS DURING CONTINUOUS EXERCISE WITH STABLE HEART RATE DETERMINED FROM CONCONI TEST

The aim of this study was to verify the blood lactate levels during 45 minutes continuous exercise with stable heart rate (HR), corresponding to heart rate deflection point (HRDP). Eight male volunteers, trained cyclists (23,2 ± 4,4 years old; maximal oxygen consumption of 63,8 ± 6,0 $ml.kg^{-1}.min^{-1}$) participated in this study. Seven from the eight volunteers which performed a modified Conconi test in cycloergometer, showed HRDP. One week later, the seven subjects performed an exercise during 45 minutes in a cycloergometer with a stable HR within a HR zone which corresponded to HRDP minus five heart beats per minute (bpm). All of the seven subjects were able to perform the exercise in the intensity prescribed during the

45 minutes. The lactate levels in minutes 5 and 15 were significantly different from 4 mmol/l. In the minutes 25, 35 e 45 of the exercise, the lactate levels were not different from 4 mmol/l. The results obtained in the present study indicate that the continuous exercise in the intensity prescribed by HR determined by the HRDP can be sustained for 45 minutes with blood lactate levels near to 4 mmol/l, except in the firsts minutes of exercise, which suggests a relationship between anaerobic threshold of 4 mmol/l and the HRDP determined by the Conconi test.

KEY WORDS: heart rate, lactate, Conconi

DES CONCENTRATIONS DE LACTATE SANGUIN PENDANT L'EXERCICE CONTINU AVEC UNE FRÉQUENCE CARDIAQUE STABLE DÉTERMINÉE À PARTIR DE LA MÉTHODE DE CONCONI

L'objet de cette étude a été de vérifier les concentrations de lactate sanguin pendant 45 minutes d'exercice continu avec une fréquence cardiaque (FC) stable, correspondante au point de déflexion de la fréquence cardiaque (PDFC). Huit volontaires de sexe masculin, des cyclistes entraînés (âgés de 23,2 $\pm$ 4,4 ans; avec un débit de 63,8 $\pm$ 6,0 ml.kg^{-1}.min^{-1}) ont participé de cette étude. Sept volontaires sur huit soumis à un test de Conconi modifié par cycloergomètre ont présenté un PDFC. Après une semaine, les sept sujets ont réalisé un exercice pendant 45 minutes, sur un cycloergomètre, avec la FC stable dans une zone qui comprenait la FC au point de déflexion moins cinq battements par minute (bpm). Tous les sept sujets ont été capables de réaliser l'exercice à l'intensité prescrite pendant 45 minutes. Les niveaux de lactate sanguin aux minutes 5 et 15 ont été significativement différents de la valeur 4 mmol/l. Aux minutes 25, 35 et 45 de l'exercice, les niveaux de lactate sanguin n'ont pas été significativement différents de 4 mmol/l. Les résultats obtenus par la présente étude indiquent que l'exercice continu, avec une intensité prescrite par la FC déterminée par le point de déflexion de la FC peut être soutenu par 45 minutes avec des niveaux de lactate sanguin proches de 4 mmol/l, sauf dans les premières minutes d'exercice, ce qu'on suggère un rapport entre le seuil anaérobique de lactate de 4 mmol/l et le PDFC déterminé par la Méthode de Conconi.

MOTS-CLÉ: fréquence cardiaque, lactate, Conconi

CONCENTRACIONES DE LACTATO SANGUINEO DURANTE EL EJERCICIO CONTINUADO CON LA FRECUENCIA CARDIACA ESTABLE DETERMINADA A PARTIR DEL MÉTODO DE CONCONI

El objeto de este estúdio fue la verificación de las concentraciones de lactato sanguineo durante 45 minutos de ejercicio continuado con frecuencia cardíaca (FC) estable, correspondiente al punto de deflección de la frecuencia cardíaca (PDFC). Fueron ocho los voluntários del sexo masculino, ciclistas entrenados (edad 23,2 $\pm$ 4,4 anos; consumo máximo de oxígeno de 63,8 $\pm$ 6,0 ml.kg^{-1}.min^{-1}), que participaron de esta pesquisa. De los ocho voluntários sometidos al test de Conconi cambiado para cicloergometro, siete de ellos presentaron el PDFC. Tras una semana, los siete indivíduos realizaron un ejercicio por 45 minutos, en el cicloergometro, con la frecuencia cardíaca estable dentro de una zona que comprendia la FC en el punto de deflección menos 5 latidos por minuto. Los siete indivíduos, en su totalidad, fueron capaces de realizar el ejercicio en la intensidad deseada por 45 minutos. Los niveles de lactato sanguineo observados en los minutos 5 y 15 fueron significativamente distintos del valor de 4 mmol/l. En los minutos 25, 35 y 45 del ejercicio, los niveles de lactato sanguineo no fueron significativamente diferentes de 4 mmol/l. Los resultados obtenidos en este estúdio indican que el ejercicio continuado, con intensidad prescripta por la FC determinada por el PDFC puede ser sostenido por 45 minutos tenendo los niveles de lactato próximos de 4 mmol/l, excepto en los primeros minutos de ejercicio, lo que sugiere una relación dentre el umbral anaeróbico de lactato de 4 mmol/l y el PDFC determinado por el método de Conconi.

PALABRA-LLAVE: frecuencia cardiaca, lactato, Conconi

CONCENTRAÇÕES DE LACTATO SANGUÍNEO DURANTE EXERCÍCIO CONTINUO COM FREQUÊNCIA CARDÍACA ESTÁVEL DETERMINADA A PARTIR DO MÉTODO DE CONCONI

O objetivo deste estudo foi verificar as concentrações de lactato sangüíneo durante 45 minutos de exercício contínuo com freqüência cardíaca (FC) estável, correspondente ao ponto de deflexão da freqüência cardíaca (PDFC). Oito voluntários do sexo masculino, ciclistas treinados (idade de 23,2 $\pm$ 4,4 anos; consumo máximo de oxigênio de 63,8 $\pm$ 6,0 ml.kg^{-1}.min^{-1}) participaram do estudo. Sete dos oito voluntários submetidos a um teste de Conconi modificado para cicloergômetro apresentaram um PDFC. Uma semana após, os sete indivíduos realizaram um exercício durante 45 minutos, em um cicloergômetro, com a FC estável dentro de uma faixa que compreendia a FC no ponto de deflexão menos cinco batimentos por minuto (bpm). Todos os sete sujeitos foram capazes de realizar o exercício na intensidade prescrita durante 45 minutos. Os níveis de lactato sangüíneo nos minutos 5 e 15 foram significativamente diferentes do valor de 4 mmol/l. Nos minutos 25, 35 e 45 do exercício, os níveis de lactato sangüíneo não foram significativamente diferentes de 4 mmol/l. Os resultados obtidos no presente estudo indicam que o exercício contínuo, com intensidade prescrita pela FC determinada pelo ponto de deflexão da FC pode ser sustentado por 45 minutos com níveis de lactato sanguíneo próximos de 4 mmol/l, exceto nos primeiros minutos de exercício, o que sugere uma relação entre o limiar anaeróbico de lactato de 4 mmol/l e o PDFC determinado pelo método de Conconi.

PALAVRAS-CHAVE: freqüência cardíaca, lactato, Conconi.