Eur J Appl Physiol (1999) 80:34–40

ORIGINAL ARTICLE

Herbert Gustavo Simões · Carmen Sílvia Grubert Campbell
Eduardo Kokubun · Benedito Sérgio Denadai
Vilmar Baldissera

Blood glucose responses in humans mirror lactate responses for individual anaerobic threshold and for lactate minimum in track tests

Accepted: 25 January 1999

Abstract The equilibrium point between blood lactate production and removal (La^-_{min}) and the individual anaerobic threshold (IAT) protocols have been used to evaluate exercise. During progressive exercise, blood lactate $[La^-]_b$, catecholamine and cortisol concentrations, show exponential increases at upper anaerobic threshold intensities. Since these hormones enhance blood glucose concentrations $[Glc]_b$, this study investigated the [Glc] and $[La^-]_b$ responses during incremental tests and the possibility of considering the individual glucose threshold (IGT) and glucose minimum (Glc_{min}) in addition to IAT and La^-_{min} in evaluating exercise. A group of 15 male endurance runners ran in four tests on the track 3000 m run (v_{3km}); IAT and IGT – 8 × 800 m runs at velocities between 84% and 102% of v_{3km}; La^-_{min} and Glc_{min} – after lactic acidosis induced by a 500-m sprint, the subjects ran 6 × 800 m at intensities between 87% and 97% of v_{3km}; endurance test (ET) – 30 min at the velocity of IAT. Capillary blood (25 μl) was collected for $[La^-]_b$ and $[Glc]_b$ measurements. The IAT and IGT were determined by $[La^-]_b$ and $[Glc]_b$ kinetics during the second test. The La^-_{min} and Glc_{min} were determined considering the lowest $[La^-]$ and $[Glc]_b$ during the third test. No differences were observed ($P < 0.05$) and high correlations were obtained between the velocities at IAT [283 (SD 19) and IGT 281 (SD 21) m. · min^{-1}; $r = 0.096$; $P < 0.001$] and between La^-_{min} [285 (SD 21)] and Glc_{min} [287 (SD 20) m. · min^{-1} $r = 0.77$; $P < 0.05$]. During ET, the $[La^-]_b$ reached 5.0 (SD 1.1) and 5.3 (SD 1.0) mmol · l^{-1} at 20 and 30 min, respectively ($P > 0.05$). We concluded that for these subjects it was possible to evaluate the aerobic capacity by IGT and Glc_{min} as well as by IAT and La^-_{min}.

Key words Individual anaerobic threshold · Lactate minimum · Individual glucose threshold · Glucose minimum · Aerobic capacity evaluation

H.G. Simões (✉) · V. Baldissera
Department of Physiological Sciences
at São Carlos Federal University – UFSCar,
Av. Dante Jordão Stoppa, 404. AP 21,
Bl 12. CEP-08820-390-Mogi das Cruzes, São Paulo, Brazil

C.S. Grubert Campbell
Department of Physical Education at Mogi das Cruzes
University – UMC, Mogi das Cruzes, SP, Brazil

E. Kokubun · B. S. Denadai
Department of Physical Education at Paulista State
University – UNESP, Rio Claro, São Paulo, Brazil

Introduction

The blood lactate concentration $[La^-]_b$ response to exercise has been used for the evaluation of physical fitness (Chicharro and Arce 1991; Weltman 1995), for prescription of training intensity (Kinderman et al. 1979; Jacobs 1986), and for the detection of adaptations to chronic exercise (Denis et al. 1982; Keith et al. 1992). The anaerobic threshold (AT) determination from $[La^-]_b$ has been used extensively for the diagnosis of aerobic capacity (Hollman 1985) and has been shown to have high correlation with endurance (Tanaka et al. 1984; Kumagai et al. 1982). There are many incremental tests that utilize $[La^-]_b$ responses for aerobic diagnosis. The individual anaerobic threshold – IAT (Stegmann et al. 1981) and the equilibrium point between blood lactate production and removal – La^-_{min} (incremental test preceded by supramaximal exercise to induce hyperlactacidaemia; Tegtbur et al. 1993) are protocols that have used $[La^-]_b$ measurements for the diagnosis of aerobic capacity. Both IAT (Schnabel et al. 1982; Coen et al. 1991; Urhausen et al. 1994; Schuetz et al. 1995) and La^-_{min} (Tegtbur et al. 1993; Simões et al. 1995; Jones and Doust 1998) have been used to determine exercise intensities for training and scientific investigation.

The validity of IAT and La^-_{min} tests for aerobic diagnosis and AT identification has been demonstrated (Stegmann and Kindermann 1982; Coen et al. 1991; Tegtbur et al. 1991; McLellan and Jacobs 1993; Baldissera et al. 1998). It has been found that IAT and La^-_{min}

are highly correlated both with endurance and other protocols that determine AT (Coen et al. 1994; Simões 1997; Jones and Doust 1998).

It has been should that during exercise there is an increase in concentrations of catecholamines, cortisol, growth hormone, and glucagon (Schnabel et al. 1982; Hargreaves and Richter 1988; Urhausen et al. 1994). The relationships between metabolic hormone responses and the $[La^-]_b$ response has been demonstrated. Port (1991) has verified that serum cortisol concentration increased exponentially when intensities above AT were reached during an incremental test and that the inflection point in the cortisol concentration curves, both in serum and in saliva, were coincident with onset of blood lactate accumulation. Urhausen et al. (1994) have shown that the catecholamine concentration curve was similar to the $[La^-]_b$ curve at different exercise intensities. Chmura et al. (1994) have verified a coincident inflection point in $[La^-]_b$ and adrenaline concentration curves during incremental tests. Schnabel et al. (1982) have observed that, during continuous running at the velocity of IAT the $[La^-]_b$ steady state was attended by a steady state in the concentration of other metabolic and hormonal variables such as adrenaline, growth hormone, glucagon, and blood glucose $[Glc]_b$.

The glucose availability during exercise can be enhanced by activity of metabolic hormones. It has been shown that hepatic glycogenolysis and glyconeogenesis are stimulated by glucagon (Wasserman et al. 1991) and that activity of the sympathetic nervous system further stimulates catecholamine induced glycogenolysis (Winder 1985).

The increase in the concentrations of some metabolic hormones has been related both to glycogenolysis and lactate production during exercise (Exton 1979; Naveri et al. 1985; Frey et al. 1997). Considering that both $[La^-]_b$ and $[Glc]_b$ response can be related to each other during incremental exercise tests, and that the IAT protocol has been adapted to the track environment, the purposes of this study were:

1. To investigate the $[Glc]_b$ and $[La^-]_b$ responses during incremental IAT and La^-_{min} track tests
2. To investigate the possibility of considering the individual glucose threshold (IGT) and glucose minimum (Glc_{min}) in addition to IAT and La^-_{min} for the evaluation of aerobic capacity
3. To investigate the $[La^-]_b$ response during 30 min running at the velocity of IAT determined on a running track.

Methods

Subjects

The Ethics Committee approved the methods used in this study. After having signed a consent form covering the risks and benefits of the study, 15 male endurance runners volunteered to participate in this investigation. The average time the subjects had been training was 8 (SD 3.4) years. They had all been participating in endurance events at national level. Their ages, (body masses, heights, percentages of body fat (% fat), and mean velocities over 3 000 m are given in Table 1. The % fat was estimated by the skinfold measurement method of Guedes (1985).

Table 1 Mean physical data of all subjects. % *Fat* Percentage of adipose tissue, *Train* mean time the subjects had been training, v_{3km} mean velocity over 3000 m run as quickly as possible

$n = 15$	Age (years)	Body mass (kg)	Height (cm)	% Fat	Train. (years)	v_{3km} ($m \cdot min^{-1}$)
Mean	25.3	62.4	170.9	11.2	8.4	308.5
SD	7.0	3.5	3.5	4.2	3.4	16.6

Procedures

The subjects took part in four running tests during a period of 1 week, on different days, at the same time of day, and at temperatures between 21 and 24°C. Not all the subjects participated in all tests. The first running test included 15 subjects. The second, third and fourth tests included 11 subjects. The subjects were instructed to have their last meal at least 3 h before the tests. The tests were performed on an outdoor track. Unfavourable environmental conditions were avoided. Before each test session the subjects performed their routine warm-up. The tests proceeded as follows

3 Km

The subjects ($n = 15$) ran 3000 m as quickly as possible and the mean running velocity was calculated for each subject (v_{3km}). The v 3km was used to prescribe the velocities of the 800 m runs during the incremental tests (Simões et al. 1996) to determine the IAT, IGT, La^-_{min} and Glc_{min}.

Determination of IAT and IGT

The subjects ($n = 11$) ran 8 × 800-m at intensities corresponding at 87%, 89%, 90%, 92%, 94%, 96%, 98%, and 103% of $v_{3\ km}$ with a 45-s rest in-between. The rhythm of the runs was controlled by a sound stimulus at each 100 m and the total time was clocked. The heart rate (HR) was monitored (Polar Sport Tester – Finland). The $[La^-]_b$ and $[Glc]_b$ were measured (Yellow Springs 2.300 S) after each run and during the 12-min post-exercise recovery. The $[La^-]_b$ kinetics during the test and post-exercise recovery was used to identify the running velocity corresponding to IAT. The velocity corresponding to IGT was similarly determined by $[Glc]_b$ kinetics. In spite of the use of a fixed distance instead of a fixed time, this test followed the model proposed by Stegmann et al. (1981) for IAT determination. Figure 1 shows the determination of IAT and IGT during 8 × 800 m for one endurance runner.

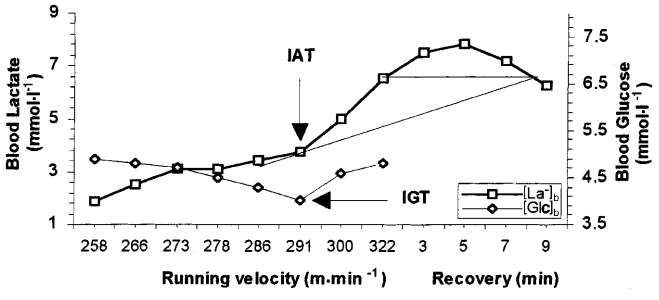

Fig. 1 Determination of *IAT* and *IGT* velocity on the track from 8 × 800-m periods of progressive exercise for a single endurance runner. For definitions see Table 2

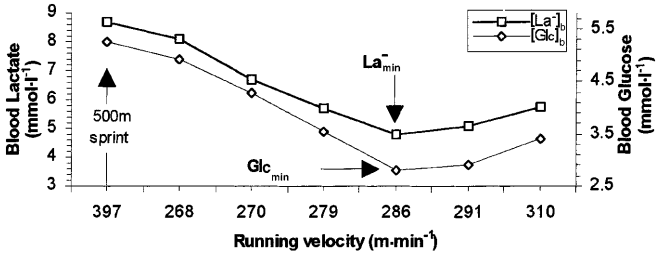

Fig. 2 Determination of La^{-}_{min} and Glc_{min} velocities from 6 × 800-m periods of progressive exercise after induction of lactic acidosis for a single endurance runner. For definitions see Table 2

Determination of La^{-}_{min} and Glc_{min}

To determine the velocity corresponding to La^{-}_{min} and Glc_{min}, the subjects (n = 11) initially sprinted all-out for 500-m to induce lactic acidosis. At 8-min of recovery after the 500-m sprint, they ran 6 × 800 m at 87%, 89%, 91%, 93%, 95%, and 98% of v_{3km}. During all 800-m runs the rhythm was controlled by a sound stimulus at each 100 m. During the 45 s rest between each run, blood was collected to measure $[La^{-}]_b$ and $[Glc]_b$. The HR was also monitored. This protocol was adapted from Tegtbur et al. (1993). The La^{-}_{min} and Glc_{min} determination for 1 subject is shown in Fig. 2. After induction of lactic acidosis the $[La^{-}]_b$ showed a reduction at the beginning of the progressive test until the AT intensities had been attained. After that, $[La^{-}]_b$ began to increase until the end of the test. The $[La^{-}]_b$ curve showed a *U-shaped* feature and the running velocity corresponding to the lowest $[La^{-}]_b$ during the progressive test was considered La^{-}_{min}. The La^{-}_{min} represented the equilibrium point between blood lactate production and removal (Tegtbur et al. 1993). The [Glc] response during the test mirrored the $[La^{-}]_b$ responses. So the Glc_{min} was determined as the velocity corresponding to lowest $[Glc]_b$ during this incremental test. (Fig. 2).

Endurance test

The subjects (n = 11) ran for 30 min at velocity corresponding to the IAT determined on the track. Not all the 11 volunteers that participated in the endurance test (ET) were the same as those in the IAT, IGT, La^{-}_{min} and Glc_{min} tests. Following the same procedures as in other tests cited previously, the rhythm was controlled by a sound stimulus. After 20 and 30 min of the test, HR was measured and the exercise was stopped for 45 s for a blood collection and $[La^{-}]_b$ measurement. The purpose of this test was to investigate the $[La^{-}]_b$ and HR responses during long-term exercise performed at the velocity of IAT determined on the track.

Blood collection and laboratory analysis

A 25 µl sample of capillary blood was collected from the ear lobe using heparinized glass capillaries and deposited in Eppendorff tubes with 50 µl of 1% sodium fluorite. The $[La^{-}]_b$ and $[Glc]_b$ were determined from this sample in duplicate using a blood lactate and glucose analyser (Yellow Springs 2.300 S).

Statists treatment

The differences between velocities determined by IAT, IGT, La^{-}_{min}, and Glc_{min} were analysed using two-way ANOVA for repeated measures (protocol x substrate). Whenever necessary the means were compared by the Tukey test. The differences for $[La^{-}]_b$ and HR between 20 and 30 min of ET were analysed using Student's t-test for paired data. The relationship between velocities determined by $[La^{-}]_b$ and $[Glc]_b$ in the incremental tests was found using Pearson's correlation. The level of significance was set at $P < 0.05$.

Results

The mean time necessary to conclude the progressive exercise tests was 22 (SD 1.7) and 16.5 (SD 1.3) min for IAT and La^{-}_{min}, respectively. Figures 1 and 2 give, for a single subject, the two protocols of exercise evaluation by $[La^{-}]_b$ and $[Glc]_b$ used in this study. Using these methods it was possible to identify the velocities corresponding to IAT and IGT and at La^{-}_{min} and Glc_{min}. Figure 3 shows the mean $[La^{-}]_b$ and $[Glc]_b$ responses for all the subjects during 800-m incremental runs to determine IAT and IGT. Figure 4 shows the mean $[La^{-}]_b$ and $[Glc]_b$ responses for all the subjects after the 500-m sprint followed by the 800-m incremental runs to determine the La^{-}_{min} and Glc_{min}. The $[Glc]_b$ responses followed the same pattern as $[La^{-}]_b$ during both tests for all the subjects.

The velocity, $[La^{-}]_b$ and $[Glc]_b$ corresponding to IAT, IGT, La^{-}_{min} and Glc_{min} are given in Table 2.

No differences were observed for the velocities (P = 0.28) determined by IAT, IGT, La^{-}_{min} and Glc_{min} tests. The $[La^{-}]_b$ for IAT and La^{-}_{min} were significantly different from each other ($P < 0.001$) and no differences

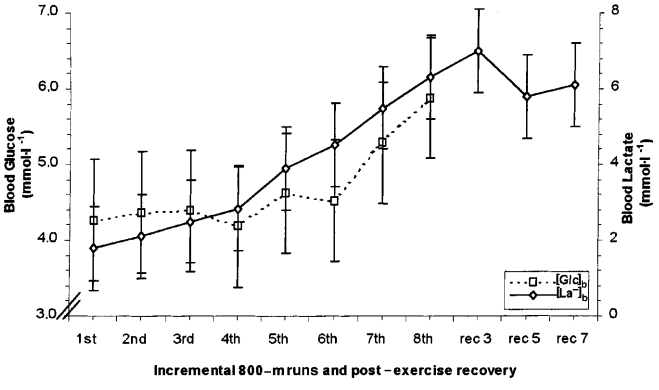

Fig. 3 Blood lactate and glucose concentration responses during 8 × 800-m periods of incremental exercise on the track for all subjects (n = 11). *rec 3*, *rec 5*, *rec 7* Recovery after 3rd, 5th and 7th min. For other definitions see Table 2

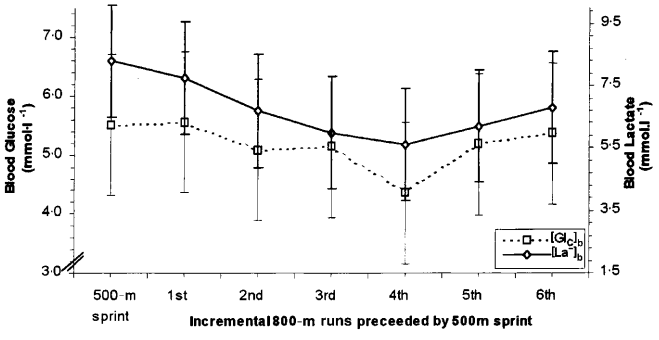

Fig. 4 Blood lactate and glucose responses during 6 × 800-m incremental track test after lactic acidosis induction by 500 m sprint for all subjects (n = 11). For definitions see Table 2

Table 2 Running velocity, blood lactate and glucose concentrations ($[La^-]_b$, $[Glc]_b$) corresponding to individual anaerobic, individual glucose thresholds (*IAT*, *IGT*), lactate minimum (La^-_{min}), and glucose minimum (Glc_{min}) ($n = 11$)

Subject	IAT		IGT		La^-_{min}		Glc_{min}	
	Run velocity ($m \cdot min^{-1}$)	$[La^-]_b$ ($mmol \cdot l^{-1}$)	Run velocity ($m \cdot min^{-1}$)	$[Glc]_b$ ($mmol \cdot l^{-1}$)	Run velocity ($m \cdot min^{-1}$)	$[La^-]_b$ ($mmol \cdot l^{-1}$)	Run velocity ($m \cdot min^{-1}$)	$[Glc]_b$ ($mmol \cdot l^{-1}$)
1	324	2.5	324	3.6	328	3.9	324	5.4
2	285	3.0	285	3.8	285	6.2	284	5.0
3	282	2.5	282	3.5	290	5.8	289	3.9
4	274	2.5	274	4.3	269	10.2	269	5.4
5	270	1.6	257	4.2	264	2.1	274	3.6
6	284	2.8	270	4.3	286	3.6	268	3.9
7	294	2.2	301	4.2	306	3.8	292	4.8
8	287	3.5	287	3.5	292	4.8	324	3.1
9	267	3.1	267	4.8	275	6.2	278	4.7
10	250	3.5	250	3.5	251	6.2	269	4.4
11	291	3.7	291	4.0	286	4.8	286	2.8
Mean	282.6	2.8	280.7	4.0	284.7	5.2*	287.0	4.3
SD	18.8	0.6	21.0	0.4	20.8	2.1	20.1	0.9

* $P < 0.05$ in relation at IAT

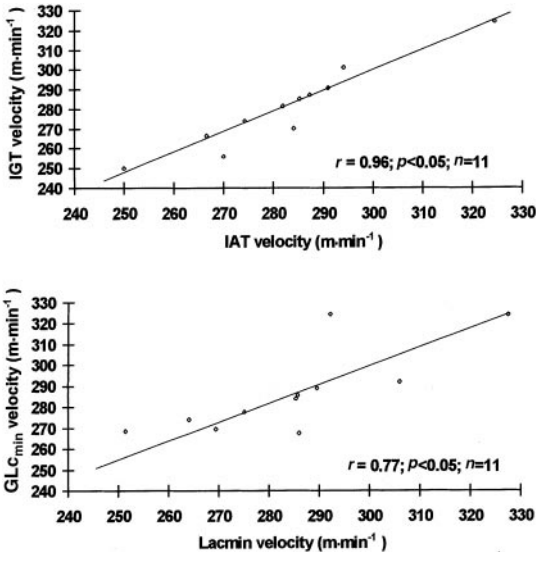

Fig. 5 Correlation between velocities determined from blood lactate and glucose concentration in two different track tests protocols – *IAT* and *IGT* (*top*) and La^-_{min} and Glc_{min} (*bottom*)

were observed for $[Glc]_b$ at IGT and Glc_{min} ($P = 0.34$; Table 2). Figure 5 shows a linear regression and a Pearson's correlation between the velocities corresponding to IAT and IGT ($r = 0.96$; $P < 0.05$) and at La^-_{min} and Glc_{min} ($r = 0.77$; $P < 0.05$).

The results of ET are given in Table 3. The $[La^-]_b$ reached 5.0 (SD 1.1) and 5.3 (SD 1.0) $mmol \cdot l^{-1}$, respectively, at 20 and 30 min during ET ($P = 0.083$). The $[La^-]_b$ reached during ET were different from the 2.88 (SD 0.5) $mmol \cdot l^{-1}$ corresponding at the IAT determined previously ($P < 0.001$). The mean HR at 30 min of ET was different from the HR corresponding to IAT determined previously ($P < 0.05$).

Discussion

The individual v_{3km} (Table 1), IAT and La^-_{min} results (Tables 2,3) are in agreement with other studies involving endurance runners and the evaluation of aerobic capacity (Coen et al. 1991; Simões et al. 1996; Campbell et al. 1996; Jones and Doust 1998). The IGT and Glc_{min} velocities were highly correlated with IAT and La^-_{min}, respectively, and no differences were observed between them (Fig. 5). It is possible to observe (Figs. 1, 3) that during the 8×800 m runs for identification of IAT and IGT, the $[Glc]_b$ showed a tendency to decline until AT velocity was attained. After this both $[Glc]_b$ and $[La^-]_b$ began to increase similarly until the end of the test. For the tests to

Table 3 Running velocity, blood lactate concentration ($[La^-]_b$) and heart rate (*HR*) corresponding at individual anaerobic threshold (*IAT*) and during 30 min endurance test at *IAT* velocity ($n = 11$)

	IAT results			Endurance test					
	IAT velocity ($m \cdot min^{-1}$)	$[La^-]_b$ IAT ($mmol \cdot l^{-1}$)	IAT HR ($beats \cdot min^{-1}$)	Velocity 20 min ($m \cdot min^{-1}$)	Velocity 20–30 min ($m \cdot min^{-1}$)	$[La^-]_b$ 20 min ($mmol \cdot l^{-1}$)	$[La^-]_b$ 30 min ($mmol \cdot l^{-1}$)	HR 20 min ($beats \cdot min^{-1}$)	HR 30 min ($beats \cdot min^{-1}$)
Mean	281.2	2.88	175.5	281.7	281.1	5.0*	5.3*	179.0	180.9*
SD	17.3	0.6	10.5	17.0	17.9	1.1	1.0	10.1	9.9

* $P < 0.05$ in relation to *IAT*

identify La^-_{min} and Glc_{min} (Figs. 2,4), the $[Glc]_b$ accompanied the $[La^-]_b$ response during the 6×800 m runs preceded by the 500-m sprint. Both $[La^-]_b$ and $[Glc]_b$ diminished until they reached La^-_{min} and thereafter increased again. This similarity between the $[La^-]_b$ and $[Glc]_b$ curves was common during both IAT and La^-_{min} tests for all the subjects in this study (Figs. 3, 4).

One possible explanation for the similar $[Glc]_b$ and $[La^-]_b$ behaviour after the IAT or La^-_{min} intensities were attained was the increase in adrenergic activity which occurred after this. Adrenaline and glucagon have been related as the main hormones to enhance blood $[Glc]_b$ during exercise (Winder 1985; Wasserman et al. 1991). However, it has been found that adrenaline activity promotes the most potent and rapid control of glycogenolysis during exercise and this control depends on exercise intensity (Winder 1985). Some studies have suggested that there is a threshold intensity for high adrenergic activation (Clutter et al. 1980) and that adrenaline stimulates both glycogenolysis and lactate production during exercise (Exton 1979; Stainsby et al. 1991). Urhausen et al. (1994) have found that during exercise at intensities above AT both the $[La^-]_b$, $[Glc]_b$ and catecholamine responses are higher than during exercise at intensities under AT. Marliss et al. (1991) have investigated the glucoregulatory and hormone responses to repeated periods of intense exercise in humans and found significant correlations ($P < 0.002$) between blood glucose production and plasma noradrenaline ($r = 0.82$) and adrenaline ($r = 0.70$). These data suggest a major regulatory role for catecholamines responses in glucose homeostasis.

Many authors have shown that the aerobic-anaerobic transitions (e.g. ventilation threshold, onset of blood lactate accumulation, lactate threshold) correspond to exercise intensities between 69% and 85% of maximal oxygen uptake ($\dot{V}O_{2\ max}$) (Tanaka et al. 1984; Ribeiro et al. 1986; Weltman et al. 1990; Coyle 1995). Exercise intensities above 75% $\dot{V}O_{2max}$ have been regarded as being sufficient to induce increments in blood $[Glc]_b$ above resting levels (Pruett 1970; Hartley et al. 1972). In our study, the blood $[Glc]_b$ showed a decrease at the beginning of the test until IAT and La^-_{min} velocities were attained. After IAT and La^-_{min} velocities were attained, both the $[La^-]_b$ and $[Glc]_b$ curves showed similar increases during the tests. It has been found that during exercise both glycogenolysis and lactate production are stimulated by adrenaline (Stainsby et al. 1991; Winder 1985). Richter et al. (1988) and Vranic et al. (1984) have suggested that glucose uptake by skeletal muscle diminishes when the blood adrenaline concentrations are enhanced. High concentrations of circulating adrenaline augment both $[La^-]_b$ and $[Glc]_b$ and diminish glucose uptake. It is possible that in this study glucose consumption was higher than glucose production at velocities below IAT and La^-_{min}. However, above the IAT and La^-_{min} velocities the glucose production was probably higher than glucose uptake by skeletal muscles and the $[Glc]_b$ responses mirror $[La^-]_b$ responses for both IAT and La^-_{min}.

In this study it was possible to determine the IGT and Glc_{min} in addition to the IAT and La^-_{min} due to the similarity between $[Glc]_b$ and $[La^-]_b$ responses during the tests. No differences were observed among IAT, IGT, La^-_{min} and Glc_{min} velocities and a high correlation was found between IAT-IGT and La^-_{min}-Glc_{min} (Fig. 5). These results showed the possibility of using glucose measurements for aerobic diagnosis because the $[Glc]_b$ responses were similar to $[La^-]_b$ responses in two distinct protocols. The IAT protocol began from rest and the periods of progressive exercise were completed in 22 (SD 1.7) min. The La^-_{min} protocol began after induction of lactic acidosis by maximal anaerobic exercise and the periods of progressive exercise were completed in 16.5 (SD 1.3) min. These methodological differences between the protocols reduce the possibility of this data being protocol dependent. However, in spite of the association between IAT and IGT and between La^-_{min} and Glc_{min} more studies need to be done to verify the validity of IGT and Glc_{min} protocols for the evaluation of exercise.

The use of $[Glc]_b$ for IGT and Glc_{min} determination must adhere to some criteria. It can be seen that in the present methods individual velocities and slow increments of about $\pm 2\%$ of v_{3km} ($\pm 6\ m \cdot min^{-1}$) were used in progressive tests.

The $[Glc]_b$ at the moment of the IGT and Glc_{min} (Table 2) were 4.0 (SD 0.4) $mmol \cdot l^{-1}$ and 4.3 (SD 0.9) $mmol \cdot l^{-1}$, respectively. No differences were observed between them although the protocols were different. However, with these methods the most important factors were the $[Glc]_b$ and $[La^-]_b$ responses rather than the concentration values alone.

The $[La^-]_b$ values corresponding at La^-_{min} were higher than IAT ($P < 0.05$; Table 2). The higher $[La^-]_b$ for the La^-_{min} can be explained by the lactic acidosis induced previously while the IAT test began from a condition of rest.

During ET, the HR and $[La^-]_b$ responses at IAT velocity (Table 3) were in agreement with those of McLellan and Jacobs (1993) and Urhausen et al. (1993). These studies have shown that a $[La^-]_b$ steady state could be observed during long-term exercise performed at IAT velocity. In our study both the $[La^-]_b$ and HR stabilized between 20 and 30 min of ET. Table 3 shows that HR corresponding to IAT previously determined was different from HR during ET. This result showed the limitation of setting HR values for the prescription of training. Also, the $[La^-]_b$ during ET [5.0 (SD 1.1) to 5.3 (SD 1.0) $mmol \cdot l^{-1}$] were substantially higher than $[La^-]_b$ reported during the IAT test [2.88 (SD 0.6) $mmol \cdot l^{-1}$; Table 3]. One possible explanation for these differences is the shorter duration of the 800-m run during the IAT test while ET had sufficient time (30 min) to elicit more significant $[La^-]_b$ and haemodynamic responses.

Many studies of IAT have reported different $[La^-]_b$ for IAT and different $[La^-]_b$ values during prolonged steady-state exercise performed at the intensity of IAT. Stegmann and Kinderman (1982) have found that $[La^-]_b$

at the intensity of IAT were around 2.4 to 6.1 mmol · l^{-1}, while during prolonged exercise the stabilization values for $[La^-]_b$ ranged between 3.1 and 4.5 mmol · l^{-1}. Schnabel et al. (1982) have related stabilization values for $[La^-]_b$ scattered between 2.7 and 6.0 mmol · l^{-1} during long-term running at the velocity of IAT. The $[La^-]_b$ reached at 20 and 30 min of ET in the present study (Table 3) give some consistency for IAT determination on the track. However it is not possible to affirm that it represents a maximal $[La^-]_b$ steady-state velocity. It has been shown that the determination of maximal $[La^-]_b$ steady-state velocity involves four or five steady-state runs of approximately 30 min (Jones and Doust 1998; Heck et al. 1985) and that was not the purpose of this study. Other studies must therefore be made to determine the maximal velocity of the $[La^-]_b$ steady state and to correlate it with IAT, IGT, La^-_{min} and Glc_{min} velocities.

It was concluded that

1. The $[Glc]_b$ responses were similar to the $[La^-]_b$ responses during two different incremental tests
2. For these subjects it was possible to consider IGT and Glc_{min} as well as IAT and La^-_{min} for the evaluation of aerobic capacity
3. The $[La^-]_b$ showed a steady state during 30 min running at IAT velocity determined on the track.

Acknowledgements The authors would like to express their gratitude to members of the Laboratory of Biodynamics at (UNESP) Universidade Estadual Paulista, Rio Claro, São Paulo, Brazil, for their technical assistance; and to (FAPESP) Fundação de Amparo à Pesquisa do Estado de São Paulo for the financial support. In addition, the time and effort of the subjects were appreciated.

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