



ORIGINAL ARTICLE

Effects of continuous and intermittent endurance exercise in autonomic balance, rating perceived exertion and blood lactate levels in healthy subjects



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KEYWORDS

Autonomic balance;
Blood lactate;
Rating of perceived exertion;
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Abstract

Purpose: The aim of this study was to determinate the changes in the Autonomic Balance, Rating Perceived Exertion (RPE) and blood lactate after continuous versus intermittent exercise protocols.

Methods: Seven active and healthy male (33 ± 5.1 years) participated in the study. Each subject performed two exercise protocols: (i) a continuous exercise at 110% of the lactate threshold (CONT). The CONT protocol consisted in continuous running, and the distance covered was the same in meters as it was in the intermittent session, and (ii) an intermittent exercise at 100% of the Peak Treadmill Velocity (INTT). The protocol consisted of 30 min of 15 s running, interspersed with 15 s of passive rest. Autonomic balance was assessed through the LF/HF ratio, before beginning the exercises, immediately finishing the exercises and 24 h post-exercise; RPE was evaluated every 5 min in each exercise protocol; and blood lactate was measured immediately after both protocols. Alpha level was set at $P \leq .05$.

Results: Autonomic balance did not show significant differences between protocols ($P = .60$). RPE during INTT exercise was significantly higher than CONT exercise ($P = .01$). Blood lactate levels after exercise did not show significant differences ($P = .68$). Heart rate variability parameters in the time domain (mean RR and pNN50) show no statistical differences between both protocols pre and 24 h post exercise ($P = .24$ and $P = .61$, respectively).

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PALABRAS CLAVE

Balace autonómico;
Lactato en sangre;
Percepción subjetiva
del esfuerzo;
Ejercicio
intermitente

Conclusions: The data suggest that intermittent exercise is perceived more intense than continuous, although both protocols showed similar internal loads in autonomic balance and blood lactate levels.

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Efectos del ejercicio de resistencia continuo e intermitente sobre el balance autonómico, la escala de esfuerzo percibido y los niveles de lactato en sangre en sujetos sanos

Resumen

Objetivo: La finalidad de este estudio fue determinar los cambios en el balance autónomo, la percepción subjetiva del esfuerzo (PSE), y el lactato sanguíneo después de un protocolo de ejercicio aeróbico continuo y uno intermitente.

Métodos: En el estudio participaron 7 varones activos y sanos ($33 \pm 5,1$ años). Cada sujeto realizó 2 protocolos de ejercicios: a) un ejercicio continuo al 110% del umbral del lactato (CONT); el protocolo CONT consistió en una carrera continua, siendo la distancia cubierta en metros igual a la distancia de la sesión intermitente, y b) un ejercicio intermitente al 100% de la velocidad pico en cinta (INTT). El protocolo consistió en 30 min de carrera de 15 segundos, intercalados con 15 segundos de descanso pasivo. El balance autónomo se evaluó mediante el ratio LF/HF antes de comenzar los ejercicios, inmediatamente después de finalizar los mismos, y a las 24 h de su finalización; la RPE se evaluó cada 5 min en cada protocolo de ejercicios, y el lactato en sangre se midió inmediatamente tras ambos protocolos. El nivel alfa se estableció en $p \leq 0,05$.

Resultados: El balance autónomo no reflejó diferencias significativas entre ambos protocolos ($p = 0,60$). La RPE durante el ejercicio INTT fue considerablemente superior al ejercicio CONT ($p = 0,01$). Los niveles de lactato en sangre no reflejaron diferencias significativas ($p = 0,68$). Los parámetros de variabilidad de la frecuencia cardiaca en el dominio del tiempo (RR medio y pNN50) no reflejaron diferencias estadísticas entre ambos protocolos, con mediciones previas y a las 24 h del ejercicio ($p = 0,24$ y $p = 0,61$, respectivamente).

Conclusiones: Los datos sugieren que el ejercicio intermitente se percibe más intenso que el continuo, aunque ambos protocolos reflejaron cargas internas similares en cuanto a balance autónomo y niveles de lactato en sangre.

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Introduction

Recovery after exercise, that is, return of body homeostasis after training is important to obtain training adaptations and its control may provide useful data for the individualization of training loads.¹ Rating of perceived exertion (RPE) allows to monitor training intensity,² being an accessible tool for training control. From a metabolic view, blood lactate (production vs removal) can be used to evaluate glycolytic activity and to assist with determining training exercise intensity.³ Heart Rate Variability (HRV) analysis is a non-invasive measurement of cardiac control of the autonomic nervous system,^{4,5} and can be used as a monitoring tool to control training loads.¹ Frequency and time domain are the most used methods for HRV analysis in different physiological conditions.^{5,6} LF/HF ratio can be used as a measure of autonomic balance.^{1,5,7} It has been reported that HRV indexes are modified by

exercise training at different intensities,⁸ been continuous endurance training of low and moderate intensities the most studied type of exercise related to HRV.^{9,10}

Although low to moderate exercise intensity (close to LT intensity) has been proposed systematically to modulate vagal activity,^{9,10} to obtain complete adaptation in the cardiovascular system and vagal activity should be performed a combination of moderate and high intensity aerobic exercise.^{11,12} Recent studies have shown that intermittent exercise may have an important role in achieving these goals,¹³⁻¹⁵ however, these adaptations are both, primarily peripherally or acute effects and little is known about HRV, RPE, and lactate responses to intermittent exercise. The aim of this study is to analyze the response of autonomic balance, RPE and blood lactate levels in continuous exercise at 110% of lactate threshold (LT), and intermittent exercise at 100% of Peak treadmill velocity (PTV) in healthy subjects.

Materials and methods

Subjects

Seven active male subjects with the anthropometric characteristics shown in Table 1 were recruited from a private sport center and voluntarily agreed to participate in this experimental and cross-sectional study. All subjects were healthy and underwent no medical treatment at the moment of the evaluations. Inclusion criteria was that the subjects train moderate to high intensity exercises at least 3 times a week for at least the last 2 years, regardless of the discipline performed, and had no musculoskeletal injuries at the time of exercise test and training sessions.

Subjects were instructed to fast for at least 3 h before exercise test and training sessions, to restrain from ingesting beverages containing caffeine or alcohol and not to exercise during the 24 h prior and before the test and exercise sessions.

Participants were informed of the purpose of the study, the experimental procedures implicated and all the potential risks involved before obtaining written consent. All participants were deemed healthy based on their response to a routine medical screening questionnaire. The study was conformed to standards for the use of human subjects of research as outlined in the current Declaration of Helsinki.

Experimental design

Peak treadmill velocity (PTV) determination

After a 10-min warm up at 8 km h^{-1} the subjects performed an incremental test with an initial velocity of 7 km h^{-1} and a 0% inclination. The treadmill velocity was increased every minute in 1 km h^{-1} until exhaustion.¹⁶ The peak treadmill velocity (PTV) is defined as the final velocity reached and maintained for one minute for a maximum incremental test, which is associated with VO_2max ¹⁷ and significantly correlated with the Maximal Aerobic Speed ($v\text{VO}_2\text{max}$) ($r=0.90$).¹⁸ Determination of Lactate Threshold (LT) was conducted through the HRV and following the criteria used by Sales et al.¹⁹ Briefly, during low to moderate exercise intensity the heart rate increase is mainly controlled by the parasympathetic nervous system (PNS) withdrawal, but at higher intensities there is a reduction in

the parasympathetic modulation concomitant to an increase in sympathetic activity. The R-R intervals were analyzed by the time domain through the square root of the mean squared successive differences between adjacent R-R intervals (rMSSD) which is related to parasympathetic activity.²⁰ For the determination of LT, stabilization point lower than 3 milliseconds (ms) was adopted for of the vagal activity indices (rMSSD) plotted against the absolute training load.

The PTV and LT were used to determine exercise intensity. All subjects completed both exercise sessions in a random order.

Intermittent exercise (INTT) at 100% of PTV

After an 8-min warm-up at 8 km h^{-1} , and followed by 5 min stretch circuit, the subjects performed intermittent session. The session consisted of 30 min at 100% of PTV obtained in the incremental test with a protocol of 15 s of work, interspersed with 15 s of passive rest.

Continuous exercise (CONT) at 110% of AT

After an 8-min warm-up at 8 km h^{-1} , and followed by 5 min stretch circuit, the subjects performed continuous session. The session consisted in continuous running at 110% of LT obtained in the incremental test, and the distance covered was the same in meters as it was in the INTT session.

Data collection instruments

Heart rate variability

Subjects were referred to the laboratory during morning and all measurements were made between 8:00 am and 11:00 am.

Simultaneous R-R interval recordings were made during a 10-min supine rest period using a Polar RS800CX heart rate monitor (Polar Electro OY, Kempele, Finland), which has been validated in previous studies.²¹

R-R measures were obtained pre, immediately post and 24 h post exercise session. The data were resampled at 4 Hz and detrended with a 1st order method for subsequent analysis in Kubios Software HRV 2.0 (Biosignal Analysis and Medical Imaging Group, Kuopio, Finland). The spectral analysis was performed with the Fast Fourier Transform (FFT) to quantify the power spectral density of the low frequency (LF; 0.04–0.15 Hz), and the high frequency (HF; 0.15–0.40 Hz) bands. Additional calculations included the LF/HF ratio to quantify the autonomic balance.

Blood lactate determination

Blood lactate values were obtained via a finger prick capillary blood sample immediately after each exercise protocol as was previously described.²² Samples were analyzed immediately for whole blood lactate concentration (mmol/L) using a standard enzymatic lactate analyzer Accutrend (Roche, Mannheim, Germany).

Rating perceived exertion (RPE)

RPE was quantified every 5 min until the end of the session using the CR10 Borg Scale.²³ During each exercise session subjects had a visual layout of Borg's scale to control the perceived intensity.

Table 1 Descriptive characteristic of the subjects. Data is shown as mean \pm S.D.

Age (years)	33 \pm 5.13
Height (m)	1.74 \pm 0.05
Body mass (kg)	82.1 \pm 3.8
Body mass index (kg/m^2)	27.1 \pm 0.9
Peak treadmill velocity (km/h)	15.4 \pm 1.4
Continuous exercise volume (m)	3857 \pm 349
Intermittent exercise volume (m)	3857 \pm 349
Continuous exercise volume (min)	24.53 \pm 2.4
Intermittent exercise volume (min)	30 \pm 0
Continuous exercise intensity (%HRR)	71.4 \pm 9.3
Intermittent exercise intensity (%HRR)	73.4 \pm 5.9

HRR, heart rate reserve.

Table 2 Effects of exercise on heart rate variability. Data is shown as mean \pm S.D.

	P-CONT	PT24-CONT	P-INTT	PT24-INTT	P value
Mean RR	947 \pm 150	1007 \pm 108	976 \pm 95	959 \pm 74	0.24
pNN50	10 \pm 9	9 \pm 5	10 \pm 11	12 \pm 11	0.61
LF/HF ratio	2 \pm 0.6	1.9 \pm 0.8	1.9 \pm 1	3 \pm 2	0.60

Statistics

All data is expressed as means \pm SD. As the sample size was small, statistical analyzes were realized with non-parametric tests. Differences between basal and post exercise values were determined using Wilcoxon paired *t*-test, Friedman test and post-analysis with Dunn's multiple comparisons test. Alpha level was set at $p < 0.05$. The data was analyzed in GraphPad Prism version 5.0a (GraphPad Software, La Jolla, CA, USA).

Results

The anthropometric data of the subjects involved in the present study and the characteristics of the exercises performed are presented in Table 1. Effects of exercise on heart rate variability are shown in Table 2, and show no statistical differences between both exercise protocols.

The changes in autonomic balance are shown in Fig. 1. Fig. 1A shows significant differences in LF/HF ratio between pre and immediately post exercise in both protocols (P-CONT: 2.1 ± 0.6 ; PT-CONT: 9 ± 3 ; P-INTT: 1.6 ± 0.9 ; PT-INTT: 7.5 ± 2 ; $p = 0.0001$). Fig. 1B compare autonomic balance between pre and post 24h exercise sessions. The values of autonomic balance post 24h between both sessions reflected in LF/HF ratio were 1.6 ± 0.7 and 2.0 ± 0.8 (CONT and INTT respectively). There are no significant statistical differences between both conditions ($p = 0.60$).

Table 3 shows the comparison of blood lactate values (immediately post exercise) and RPE between exercise protocols. RPE during INTT exercise was significantly higher than CONT exercise ($p = 0.01$).

Discussion

Our study compared the effects of two exercise protocols in autonomic balance, RPE and blood lactate in male healthy subjects. Although both exercise sessions have different external loads (intensity), internal loads only show differences in RPE when the volume is equivalent in both sessions.

Related to acute autonomic balance, Parekh and Lee⁸ investigated the acute response of autonomic balance

comparing aerobic exercise at two different intensities (50% and 80% of VO_2 reserve), and taking the data during the following 30 min at the end of the exercise. Their results confirmed their hypothesis that a higher intensity exercise was associated with an increased post-exercise change in autonomic balance and showing a sympathetic predominance. Our data showed that the acute response to exercise is very similar between the two protocols. We observed no significant differences in acute autonomic balance post exercise ($p \geq 0.99$; LF/HF = 6.9 ± 3 and 7.5 ± 2), between continuous and intermittent respectively, although the intermittent session was perceived as more intense than the continuous session.

Unlike Parekh and Lee⁸ and related to cardiorespiratory response, in our research the continuous exercise was performed on an average of 63% of the PTV, and intermittent exercise at 100% of the PTV, which should display a greater modulation of autonomic balance by the SNS as intermittent exercise was conducted at a significantly higher intensity. Nevertheless, the differences were not significant, what could be because the average heart rate reserve (HRR) showed no significant differences (mean and SD of % HRR between continuous and intermittent exercise were 71 ± 9 and 73 ± 5 respectively, $p = 0.41$), whereby the relative intensity from this point of view was very similar. This could be justified with the fact that intermittent sessions have a rest period interspersed between each interval training load, leading to a longer time for exhaustion than performing the same exercise continuously, which can be sustained between 2.5 and 10 min.²⁴

Regarding to blood lactate levels at the end of the two sessions, these did not show statistically significant differences ($p = 0.68$) (mean values between continuous lactate and intermittent lactate at the end of the session were $5.5 \text{ mmol/L} \pm 1.1$ and $6.0 \text{ mmol/L} \pm 1.2$, respectively). Demarie et al.²⁴ compared intermittent exercise session performed with 30s at 100% of the vVO_2max and an active pause at 50% of the vVO_2max , resulting in mean values of lactate of 7.4 mmol/L , and a continuous exercise performed at 90% of the vVO_2max until exhaustion, where the lactate showed an average of 8.0 mmol/L . In our research the mean of intermittent training lactate was lower ($6.0 \pm 1 \text{ mmol/L}$). Is important to clarify that Demarie et al.²⁴ used a longer interval at vVO_2max (30s) compared to our protocol (15s at PTV), and they also used an active pause at 50% of the vVO_2max (30s), whereas we used a passive rest (15s). Passive rest would allow greater recovery of available oxygen in hemoglobin and myoglobin, and phosphocreatine resynthesis.²⁵ More recent data conducted by Okuno et al.²⁶ compared a continuous and intermittent session in 10 healthy students, where they performed intermittent cycle ergometer protocols at two different intensities with 30s of

Table 3 Blood lactate values and rating perceived exertion between both exercise protocols. Data is shown as mean \pm S.D.

	INTT	CONT	P value
Blood lactate	6 \pm 1	5.5 \pm 1	0.68
RPE	7 \pm 0.7	6.1 \pm 0.5	0.01*

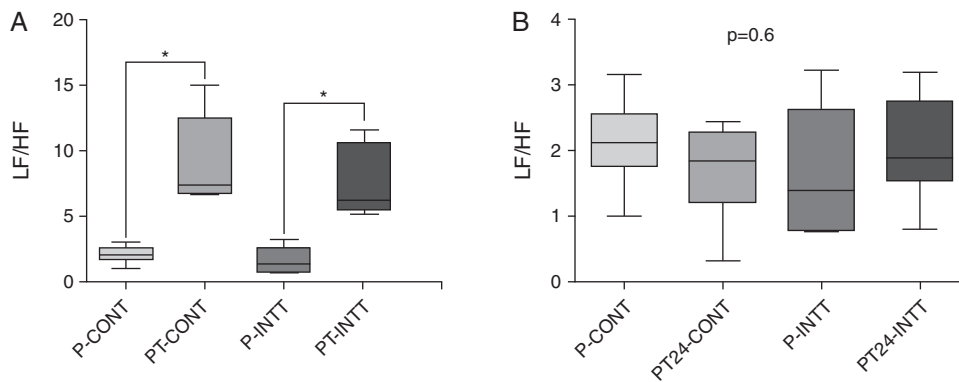


Figure 1 Comparison of autonomic balance between pre and immediately post exercise (A) and between pre and post 24 h exercise (B). LF/HF, low frequency/high frequency; P-CONT, pre continuous; P-INNT, pre intermittent; PT-CONT, post continuous; PT-INNT, post intermittent; PT24-CONT, post 24 h continuous; PT24-INNT, post 24 h intermittent. Box: Upper Hinge, 75th Percentile; Lower Hinge, 25th Percentile; Inside Hinge, Median. Whiskers: Minimum and Maximum. Plus sign: Mean. * $P < 0.05$.

exercise and 30 s of passive pause, one to the critical power (CP: power output at the lactate threshold) and the other to the maximum intensity of the lactate steady state (MLSS), obtaining lactate averages of 6.9 mmol/L and 5.1 mmol/L, respectively. Our results shows that total lactate levels in intermittent exercise was 6.0 ± 1 mmol/L, being lower in comparison to exercise at CP, but greater than the MLSS. This could be interpreted as the intensity used in our research allows greater activation of fast fibers, stimulating more the glycolytic metabolism, and thus contributing to increased production of lactate.

Concerning the AB, and in the same study conducted by Okuno et al.,²⁶ they observed the rating of perceived exertion between both protocols occupying the Borg scale of 20 points. Their results showed that the average was 17.1 (very difficult), and 15.7 (difficult), CP and MSSL respectively. When comparing the INTT session of our study with the higher intensity protocol of Okuno (CP), it can be seen that RPE was felt less intense in our research (very difficult vs difficult in Borg's Scale, Okuno et al.,²⁶ and our study, respectively).

Finally, autonomic balance values post 24 h, reflected in the LF/HF ratio, has being documented. Hynynen et al.²⁷ proposed that normal values at rest for LF/HF ratio is between 1 and 2, where values greater than 2 shows that autonomic balance is modulated mainly by the SNS and if lower than 1 it is modulated mainly by the PNS. Pober et al.¹⁰ showed that a continuous exercise session of 1 h to 65% of VO_2 peak could modulate the AB toward PNS post 24 h, which is comparable with our research in the continuous exercise session. In our study the intensity was similar (63% of the HRR), the length thereof was lower (Mean: 24.53 ± 2 min), and had an average value of 1.9 in the LF/HF ratio post 24 h, showing a modulation toward to PNS in 57% of cases, but without significant differences between pre and 24 h post exercise ($p \geq 0.99$). Mourot et al.²⁸ realized a comparison of short and long term effects on HRV between continuous and interval training session. A parameter that was considered was LF/HF ratio and made the comparison immediately, 1 h, 24 h and 48 h post exercise session. They compared a continuous exercise session at 100% of ventilatory threshold 2 (VT2), and interval training with 1 min of exercise at 100%

of maximal aerobic power (MAP) interspersed with 4 min of active rest at 100% of VT2. They found significance differences between pre and immediately post exercise in both protocols, but no significant differences in post 24 and 48 h in LF/HF ratio, compared with basal values. The basal values of LF/HF ratio were 1.0 and 1.2 in the interval and continuous group respectively, and 24 h post exercise session were 3.4 and 1.9, respectively. These results are very similar to ours, although interval exercise differs in both training load and interspersed rest. Our data show that LF/HF ratio in intermittent exercise had an average value 24 h post training of 2.1, compared with the continuous exercise which had an average value of 1.7 ($p \geq 0.99$), showing no significant differences in autonomic balance posts 24 h between two exercises protocols, results also consistent for those found by James et al.²⁹

Despite the results, they must be interpreted carefully because the size of the experimental samples was small.

Conclusions

Our findings suggest that intermittent exercise is perceived more intense than continuous, although both protocols showed similar internal loads in autonomic balance and blood lactate levels. Kinetics of autonomic balance is similar in both protocols immediately and 24 h post exercise, and could be used as a simple and non-invasive tool for monitoring exercise load in aerobic intermittent exercise. Internal loads only show differences in RPE when the volume is equivalent in both sessions, suggesting that modulation depends on other factors than exercise intensity.

Further research is needed to confirm and complement these findings, which could incorporate different types of HRV analysis, such as time-frequency analysis for thresholds determination, as well as incorporating other variables such as HR recovery and its relationship with HRV.

Conflict of interest

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

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