

## Comparison of Oxygen Uptake During and after the Execution of Resistance Exercises and Exercises Performed on Ergometers, Matched for Intensity

by

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The aim of this study was to compare the values of oxygen uptake ( $\text{VO}_2$ ) during and after strength training exercises (S<sub>Te</sub>) and ergometer exercises (Ee), matched for intensity and exercise time. Eight men ( $24 \pm 2.33$  years) performed upper and lower body cycling Ee at the individual's ventilatory threshold (VE/VCO<sub>2</sub>). The S<sub>Te</sub> session included half squats and the bench press which were performed with a load at the individual blood lactate concentration of 4 mmol/l. Both sessions lasted 30 minutes, alternating 50 seconds of effort with a 10 second transition time between upper and lower body work. The averaged overall  $\text{VO}_2$  between sessions was significantly higher for Ee ( $24.96 \pm 3.6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) compared to S<sub>Te</sub> ( $21.66 \pm 1.77 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) ( $p = 0.035$ ), but this difference was only seen for the first 20 minutes of exercise. Absolute  $\text{VO}_2$  values between sessions did not reveal differences. There were more statistically greater values in Ee compared to S<sub>Te</sub>, regarding  $\text{VO}_2$  of lower limbs ( $25.44 \pm 3.84 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  versus  $21.83 \pm 2.24 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ;  $p = 0.038$ ) and upper limbs ( $24.49 \pm 3.84 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  versus  $21.54 \pm 1.77 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ;  $p = 0.047$ ). There were further significant differences regarding the moment effect ( $p < 0.0001$ ) of both S<sub>Te</sub> and Ee sessions. With respect to the moment  $\times$  session effect, only  $\text{VO}_2$  5 minutes into recovery showed significant differences ( $p = 0.017$ ). In conclusion, although significant increases in  $\text{VO}_2$  were seen following Ee compared to S<sub>Te</sub>, it appears that the load/intensity, and not the material/equipment used for the execution of an exercise, are variables that best influence oxygen uptake.

**Key words:** strength training, ergometer exercises, aerobic exercise, ventilation.

### Introduction

There is consensus in the scientific community on oxygen uptake ( $\text{VO}_2$ ) rates being higher during, and lower after, the performance of predominantly aerobic exercises when compared with traditional strength training exercises (S<sub>Te</sub>) (Borsheim and Bahr, 2003; Burleson et al., 1998; Drummond et al., 2005; Gillette et al., 1994). However, in most studies, ergometer exercises (Ee) traditionally are used to perform what is known as aerobic-type exercise

(Sultana et al., 2012; Wang et al., 2012; Wright et al., 2012); and bars, free weights or machines are used to perform traditional anaerobic-type S<sub>Te</sub> (Bloomer 2005; De Sousa et al., 2012; Mukaimoto and Ohno, 2012; Scott et al., 2011). A relevant aspect to be considered is how to match the load and intensity between S<sub>Te</sub> and Ee, respectively.

With respect to Ee, a percentage of the maximum or reserve heart rate or  $\text{VO}_{2\max}$  is typically used to determine intensity. Traditional

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STe use a relative percentage of a one repetition maximum (1RM) to define the load (Braun et al., 2005; Burleson et al., 1998; Crommett and Kinzey, 2004). In our view, pairing or matching % VO<sub>2max</sub> with % 1RM does not guarantee the same physiological intensity between both types of exercise (Bloomer 2005; Steele et al., 2012). To be predominantly aerobic for example, rhythmic and continuous exercises that work a large muscle group should be performed with an intensity at, but not above, the accumulation of 4 mmol/l blood lactate, and/or corresponding to the ventilatory threshold (Mukaimoto and Ohno, 2012); this is not at all ensured by using a percentage of 1RM. Thus, we hypothesised that the higher values of VO<sub>2</sub> during, and lower after, Ee as compared to traditional STe, were due to the variables defining the intensity or load and not the type of devices used.

The aim of the present study was to compare VO<sub>2</sub> rates during and after predominantly aerobic exercises performed on ergometers and traditional STe that were matched using the threshold concepts of ventilation (VE/VCO<sub>2</sub>) and 4 mmol onset of blood lactate accumulation, respectively. The duration of each exercise period was 30 minutes.

## Material and Methods

To investigate the effect of STe and Ee on VO<sub>2</sub>, heart rate (HR) and ventilation (VE) values, subjects attended the laboratory for 14 different sessions (Figure 1). These sessions were performed after a 2 week period of adaptation and familiarisation with the exercises and protocols of this study. Anthropometric measurements (body mass, height and skin folds) were performed during the 1<sup>st</sup> session, followed by a 1RM test (bench press (BP) and half squat (HS), both with free weights); 1RM retests were completed during the 2<sup>nd</sup> session.

From the 3<sup>rd</sup> to the 10<sup>th</sup> session, tests were randomly conducted for determining the load to be used in STe (BP and HS) with percentages of 5, 10, 15 and 20% of 1RM to find the corresponding load at an accumulation of 4 mmol/l blood lactate.

In the 11<sup>th</sup> session, tests were performed to determine the intensity (~67% of VO<sub>2</sub> peak) to be used in Ee for the lower limbs (LL; cycle ergometry) and the 12<sup>th</sup> session was utilised for load testing of the upper limbs (UL; arm-

cycle ergometry).

In the 13<sup>th</sup> and 14<sup>th</sup> sessions, the Ee and STe tests were randomly conducted, at the selected intensity and load (respectively), and the values of VO<sub>2</sub>, HR and VE were collected 30 minutes before, during and after 30 minutes of the exercise sessions.

From the 1<sup>st</sup> to the 13<sup>th</sup> session, the time interval between sessions was 72 hours and between the 13<sup>th</sup> and the 14<sup>th</sup> sessions, 7 days. All subjects performed all sessions at the same time of the day (between 8 am and 10:30 am). Subjects did not perform any strenuous physical activity within 72 hours prior to the testing sessions and did not ingest any supplements, caffeine, or drugs/medications during that time period. Duplicate meals were consumed in the 24 hours preceding the 13<sup>th</sup> and 14<sup>th</sup> sessions.

### Participants

The sample size was estimated through the statistics software Gpower based on the error of estimation  $\alpha$  by 5%, the estimate of the effect size of 0.5,  $\beta$  power of 80% and the 95% confidence interval, which resulted in a minimum number of 8 individuals.

Eight active men (age 24 ± 2.33 years; body height 171.75 ± 7.67 cm; body mass 71.25 ± 5.78 kg; body fat (7 skin folds) (Jackson and Pollock, 1978) 7.05 ± 1.62%) completed all study procedures. All subjects included in the present study had been practising STe and Ee for at least 6 months with a minimum frequency of 3 times a week for STe and twice a week for Ee, regardless whether the modalities (ST and E) were performed during the same session or separately. Medical history and physical activity questionnaires were completed to verify whether there was any limitation that could prevent participation in the study (Anamnesis and Par-Q test) (American College of Sports Medicine, 2010). Subjects were then informed about study procedures, the possible risks and discomforts related to the experimental sessions, and then signed an informed consent form to participate. The study was conducted according to the Declaration of Helsinki and approved by the University of Trás-os-Montes and Alto Douro Research Ethics Committee (CE-013.0043).

### Maximal Strength Testing

The protocol of the 1RM test has been previously described by Kraemer and Fry (1995)

and was used in the present study for the performance of BP and HS exercises (Panatta Sport, Italy). Both exercises had high 1RM test – re-test reliability (intraclass correlation coefficients): BP ICC>0.96; and HS ICC>0.97. To minimise possible error, the following strategies were adopted: (a) specific information on the procedures and execution of the exercise was presented to each subject before testing, (b) verbal encouragement was provided to the subject during the test to promote their best effort, (c) the same bar and weight disks were used in all sessions, and (d) the rate of movement was 30 repetitions per minute (60 beats/min: 1 second concentric, 1 second eccentric) controlled by a metronome (Korg MA-330, New York, USA).

#### **Oxygen Uptake Assessment**

A maximal cardiopulmonary exercise test was performed to determine peak  $\text{VO}_2$  following a continuous incremental protocol on an upper body (UL) and lower body (LL) ergometer (SCIFIT Pro II, Berkshire, UK). All the protocols and materials used in the present study had been described by Vilaça Alves et al. (2012). The portable gas analyser (COSMED® K4b<sup>2</sup>, Roma, Italy) and the HR monitor (Wireless Double Electrode, Polar®, Kempele, Finland) were calibrated before each test according to manufacturer instructions (Cosmed, 2001). The environmental conditions and materials/equipment used were the same for all sessions (before, during and after the exercises).

The ventilatory threshold for the Ee (UL and LL) was measured as the point from which the ventilatory equivalent or coefficient of carbon dioxide (VE/VCO<sub>2</sub>) increased exponentially (after the increased ventilatory equivalent of oxygen - VE/VO<sub>2</sub>).

#### **Blood Lactate Assessment**

In order to find the load that elicited a blood lactate concentration of 4 mmol/l for the STe, during the 13<sup>th</sup> and 14<sup>th</sup> sessions subjects remained at rest for 30 minutes in the same room where the measurement of a resting metabolic rate (RMR) was made prior to performing the exercises. Blood samples (25 microlitres of capillary blood) were collected from a finger tip before and immediately after the tests using a portable analyser: Accutrend ® Plus (Roche Diagnostics GmbH, COBAS, Vokietija, Germany). The portable analyser was calibrated every

session with blood lactate concentrations of 2, 4, 10, 15 and 30 mmol/l Lactate-Kontrollsel (140 LCQ, Berlin, Germany).

These sessions consisted of 4 minutes of BP and HS exercises with the intensities of 5, 10, 15 and 20% of 1RM, performed at a rate of 60 beats/min: 1 second concentric, 1 second eccentric. The following formula was used to find the corresponding value of 4 mmol/l: load in STe = (4 mmol/l - blood lactate concentration value immediately below the 4 mmol/l) x (load corresponding to the blood lactate concentration above 4 mmol/l - load corresponding to the blood lactate concentration below 4 mmol/l) / (blood lactate concentration value immediately above the 4 mmol/l - blood lactate concentration value immediately below the 4 mmol/l) + blood lactate concentration value immediately above the 4 mmol/l.

#### **Resting Metabolic Rate Measurements**

Before the exercises in the 13<sup>th</sup> and 14<sup>th</sup> sessions, and after at least 12 hours of fasting, subjects were transported to the location of the tests by a member of the evaluation team. The subjects were then taken to a silent, low-light room, where they remained lying in a supine position with the back reclined on a marquise for 30 minutes, to evaluate oxygen uptake at rest. The RMR was calculated from the values of  $\text{VO}_2$  measured during the last 10 minutes spent at rest, with the subjects being continuously measured by the portable gas analyser K4b<sup>2</sup>. Immediately after the exercise session, the subjects returned to the same room for recovery  $\text{VO}_2$  measurements for a 30 minute period.

#### **Exercise Protocols**

*Ergometer exercise session (Ee).* Subjects performed ergometer exercises at their individual ventilatory threshold intensity (VE/VCO<sub>2</sub>), alternating the LL and UL exercises until the completion of the 30 minute session; exercise periods lasted 50 seconds with a 10 seconds transfer time between LL and UL.

*Strength training exercise session (STe).* The subjects performed HS and BP exercises for 30 minutes, with a load corresponding to an individual's blood lactate accumulation of 4 mmol/l, altering HS and BP the same way as in Ee (50 seconds exercise, 10 seconds transition time).

Since the load corresponding to a blood lactate concentration of 4 mmol/l in HS exercise

was relatively low, a wooden bar, with the same dimensions of the bar used to measure the 1RM (220 cm long; 25 mm in diameter), but only 2 kg in mass, was used. The STe were performed at a rate of 60 beats/min (1 second concentric, 1 second eccentric) until the end of the session and with exercise time (50 seconds) and transfer time (10 seconds) equal to Ee. In both sessions, the first exercise to be performed was LL.

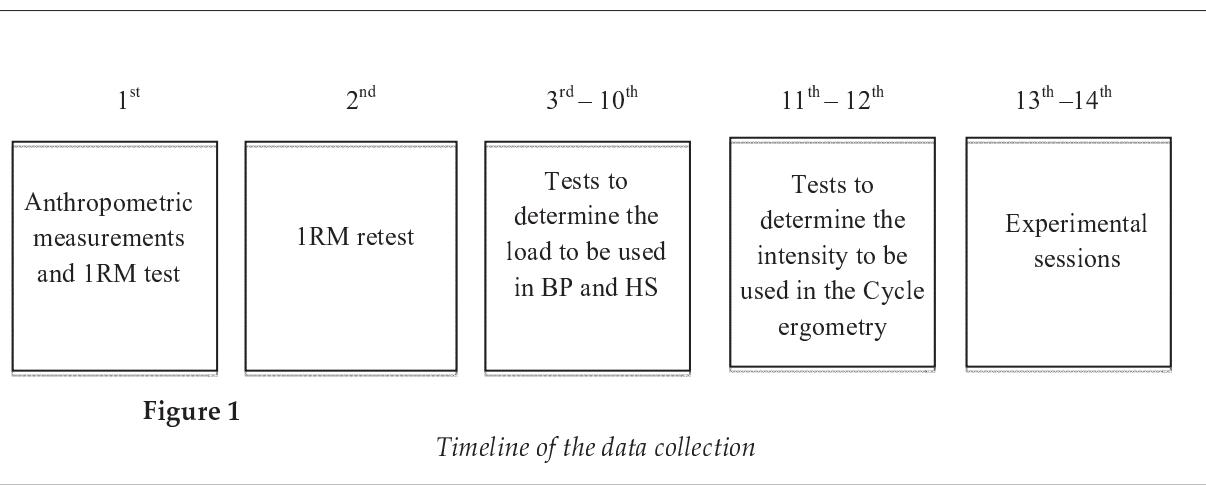
#### Statistical Analysis

An analysis of the distribution type (Shapiro-Wilk test) was conducted and then sphericity was confirmed by means of the Mauchly's sphericity test. Subsequently, ANOVA univariate testing was applied to observe the

existence of statistically significant differences between exercise sessions. An ANOVA for repeated measures with the model [7 moments x 2 exercise types] was used to assess the existence of statistically significant differences between the values of RMR and recovery VO<sub>2</sub> values (with a Bonferroni post-hoc test). The level of significance was set at 0.05. Values are presented as mean ± SD.

#### Results

The values regarding the characteristics of the subjects within each exercise session are presented in Table 1.



**Table 1**

*Performance data collected on the first 12 sessions of the present study (n=8)*

Variables	Mean ± SD
1RM Half Squat (kg)	115.63 ± 20.08
1RM Bench Press (kg)	81.88 ± 4.17
Peak VO <sub>2</sub> of Lower Limbs (ml/kg/min)	42.99 ± 4.52
Peak VO <sub>2</sub> of Upper Limbs (ml/kg/min)	32.24 ± 2.86
Load of Half Squat 4 mmol/l (kg)	3.0 ± 0.71
Load of Bench Press 4 mmol/l (kg)	10.5 ± 2.82
Ventilatory Threshold of Lower Limbs (ml/kg/min)	28.58 ± 3
Ventilatory Threshold of Upper Limbs (ml/kg/min)	21.79 ± 1.88
Load of Half Squat (%1RM)	2.70 ± 0.88
Load of Bench Press (%1RM)	12.83 ± 3.35
Ventilatory Threshold of Lower Limbs (%VO <sub>2max</sub> )	66.53 ± 2.5
Ventilatory Threshold of Upper Limbs (%VO <sub>2max</sub> )	67.62 ± 1.76

**Table 2**

*Mean values and SD of the RMR, absolute and relative VO<sub>2</sub>, Heart Rate, Ventilation, exercise and transition VO<sub>2</sub> of session and divided for Limbs (Lower and Upper) during strength training exercises and ergometers exercises (n=8).*

Variable	S <sub>Te</sub> session Mean ± SD	E <sub>e</sub> session Mean ± SD
RMR (ml/kg/min)	4.73 ± 0.84	4.57 ± 0.5
Absolute VO <sub>2</sub> (l/min)	1.55 ± 0.22	1.77 ± 0.23
Relative VO <sub>2</sub> (ml/min/kg) <sup>*</sup>	21.66 ± 1.77	24.96 ± 3.6
Ventilation (l/min)	47.35 ± 8.33	55.48 ± 8.2
Heart Rate (bpm)	118.34 ± 16.07	129.17 ± 16.2
Exercise VO <sub>2</sub> (ml/kg/min) <sup>*</sup>	22.05 ± 1.61	25.82 ± 3.56
Transition VO <sub>2</sub> (ml/kg/min)	21.59 ± 2.19	23.48 ± 3.5
Absolute VO <sub>2</sub> of Lower Limbs (l/min)	1.56 ± 0.23	1.81 ± 0.25
Absolute VO <sub>2</sub> of Upper Limbs (l/min)	1.54 ± 0.22	1.74 ± 0.21
Relative VO <sub>2</sub> of Lower Limbs (ml/kg/min) <sup>*</sup>	21.83 ± 2.24	25.44 ± 3.84
Relative VO <sub>2</sub> of Upper Limbs (ml/kg/min) <sup>*</sup>	21.54 ± 1.73	24.49 ± 3.43
Ventilation of Lower Limbs (l/min)	49.01 ± 8.19	54.42 ± 7.99
Ventilation of Upper Limbs (l/min) <sup>*</sup>	45.69 ± 8.51	56.5 ± 8.49
Heart Rate of Lower Limbs (bpm)	120.87 ± 13.69	127.02 ± 16.44
Heart Rate of Upper Limbs (bpm)	115.72 ± 18.58	131.15 ± 15.94
Exercise VO <sub>2</sub> of Lower Limbs (ml/kg/min) <sup>*</sup>	22.44 ± 2.09	26.8 ± 3.82
Exercise VO <sub>2</sub> of Upper Limbs (ml/kg/min) <sup>*</sup>	21.65 ± 1.28	24.84 ± 3.33
Transition VO <sub>2</sub> of Lower Limbs (ml/kg/min)	27.07 ± 2.5	24.29 ± 3.22
Transition VO <sub>2</sub> of Upper Limbs (ml/kg/min) <sup>*</sup>	16.12 ± 2.32	22.68 ± 3.84

\* Significant difference between the S<sub>Te</sub> and E<sub>e</sub> groups ( $p < 0.05$ ); VO<sub>2</sub> – Oxygen Uptake

**Table 3**

*Mean values and SD of relative VO<sub>2</sub> and Ventilation divided into intervals of 10 minutes during strength training exercises and ergometers exercises (n=8).*

Variable	S <sub>Te</sub> session Mean ± SD	E <sub>e</sub> session Mean ± SD
VO <sub>2</sub> 0-10 min (ml/kg/min) <sup>*</sup>	20.84 ± 1.27	24.89 ± 3.61
VO <sub>2</sub> 10-20 min (ml/kg/min) <sup>*</sup>	21.83 ± 2	25.33 ± 3.65
VO <sub>2</sub> 20-30 min (ml/kg/min)	22.31 ± 2.25	24.67 ± 3.57
Ventilation 0-10 min (l/min) <sup>*</sup>	44.14 ± 5.95	54.5 ± 8.73
Ventilation 10-20 min (l/min)	48.32 ± 9.07	56.52 ± 7.91
Ventilation 20-30 min (l/min)	49.65 ± 10.45	55.55 ± 8

\* Significant difference between the S<sub>Te</sub> and E<sub>e</sub> groups ( $p < 0.05$ ); VO<sub>2</sub> – Oxygen Uptake

**Table 4**  
*Mean values and SD of the RMR and recovery oxygen uptake ( $\text{VO}_2$ ),  
 after strength training exercises and ergometers exercises (n=8).*

Variable	St session Mean $\pm$ SD	Ee session Mean $\pm$ SD
RMR (ml/kg/min)	4.73 $\pm$ 0.84	4.57 $\pm$ 0.50
Recovery $\text{VO}_2$ 0-5 min (ml/kg/min) †*	9.86 $\pm$ 1.38	11.47 $\pm$ 1.01
Recovery $\text{VO}_2$ 5-10 min (ml/kg/min) †	6.00 $\pm$ 0.71	6.24 $\pm$ 0.80
Recovery $\text{VO}_2$ 10-15 min (ml/kg/min) †	5.87 $\pm$ 0.82	5.77 $\pm$ 0.85
Recovery $\text{VO}_2$ 15-20 min (ml/kg/min) †	5.65 $\pm$ 0.73	5.63 $\pm$ 0.68
Recovery $\text{VO}_2$ 20-25 min (ml/kg/min) †	5.50 $\pm$ 0.49	5.38 $\pm$ 0.45
Recovery $\text{VO}_2$ 25-30 min (ml/kg/min) †	5.50 $\pm$ 0.40	5.50 $\pm$ 0.54

\* Significant difference between the STe and Ee groups ( $p < 0.05$ )

† Significant difference from baseline (pre) values ( $p < 0.05$ )

No significant differences were found between sessions, ( $p > 0.05$ ), in the RMR, absolute  $\text{VO}_2$ , VE, HR and to transition  $\text{VO}_2$  (Table 2). However, average relative  $\text{VO}_2$  of the Ee session was significantly higher than that of the STe session ( $F = 5.444$ ;  $p = 0.035$ ;  $\eta_p^2 = 0.230$ ) and average exercise  $\text{VO}_2$  was also significantly higher during Ee when compared to STe ( $F = 7.469$ ;  $p = 0.016$ ;  $\eta_p^2 = 0.348$ ). Significantly higher average values in Ee compared to STe were also found regarding relative  $\text{VO}_2$  of LL ( $F = 5.267$ ;  $p = 0.038$ ;  $\eta_p^2 = 0.273$ ), relative  $\text{VO}_2$  of UL ( $F = 4.732$ ;  $p = 0.047$ ;  $\eta_p^2 = 0.253$ ), VE of UL ( $F = 6.469$ ;  $p = 0.023$ ;  $\eta_p^2 = 0.316$ ), exercise  $\text{VO}_2$  of LL ( $F = 8.020$ ;  $p = 0.013$ ;  $\eta_p^2 = 0.364$ ), exercise  $\text{VO}_2$  of UL ( $F = 6.374$ ;  $p = 0.024$ ;  $\eta_p^2 = 0.313$ ) and with transition  $\text{VO}_2$  of UL ( $F = 17.181$ ;  $p = 0.001$ ;  $\eta_p^2 = 0.551$ ) (Table 2).

Regarding the Ee session, significantly higher values were observed compared to STe in relative  $\text{VO}_2$  from 0 to 10 minutes ( $F = 8.955$ ;  $p = 0.010$ ;  $\eta_p^2 = 0.390$ ) and from 10 to 20 minutes ( $F = 5.636$ ;  $p = 0.032$ ;  $\eta_p^2 = 0.287$ ) as well as in VE from 0 to 10 minutes ( $F = 7.694$ ;  $p = 0.015$ ;  $\eta_p^2 = 0.355$ ) (Table 3). Significant differences between exercise sessions were not found regarding relative  $\text{VO}_2$  from 20 to 30 minutes and VE from 10 to 20 and from 20 to 30 minutes (Table 3). Furthermore,

there were no significant differences between sessions regarding the RMR and recovery  $\text{VO}_2$  (Table 4). However, significant differences were observed in the time effect ( $F = 184.501$ ;  $p < 0.0001$ ;  $\eta_p^2 = 0.929$ ) within the 2 sessions, namely the RMR which was significantly lower when compared to all the recovery moments ( $p < 0.05$ ) (Table 4), along with significant differences in the time effect  $\times$  session ( $F = 4.650$ ;  $p = 0.015$ ;  $\eta_p^2 = 0.249$ ). Only recovery  $\text{VO}_2$  at 5 minutes revealed a significant difference between Ee and STe sessions (Table 4).

## Discussion

We attempted to match the STe load with Ee intensity using the aerobic training concepts of ventilatory (for Ee) and lactate (for STe) thresholds. Based on this methodology, the Ee ventilatory threshold (i.e.,  $\text{VE}/\text{VCO}_2$ ) for UL and LL was found at 66.5% and 67.6% of  $\text{VO}_{2\text{max}}$ , respectively. Strength training at a 4 mmol lactate threshold resulted in exercise loads of 12.8% and 2.7% of a 1-RM for the BP and HS, respectively. At these intensities and loads, subjects alternated UL and LL exercise periods (50 seconds) with transition periods (10 seconds) for both STe and Ee, with a total exercise time of 30 minutes.

Under the conditions listed above, our

findings regarding STe loads were markedly lower compared to those of other strength training studies in which lifting loads were predominantly based on the acquisition of strength (e.g., at 60% of 1RM for untrained and 80% of 1RM or higher for trained individuals) (Rhea et al., 2003). Viewed together, average relative  $\text{VO}_2$  ( $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) for Ee often slightly, though significantly, exceeded that of STe (Table 2). Yet, differences were not found after 20 minutes of exercise (Table 3). No significant differences were found with respect to absolute  $\text{VO}_2$  values ( $\text{ml}\cdot\text{min}^{-1}$ ). Moreover, HRs were often higher in Ee, although the differences were non-significant. We may therefore conclude that, although not matched perfectly, a similar threshold was somewhat achieved for Ee and STe (a VE/VCO<sub>2</sub> threshold may reflect a greater intensity as compared to a 4 mmol blood lactate threshold (Meyer et al., 2005)).

Our research did not involve training *per se*, as only a single session was recorded to determine  $\text{VO}_2$ , HR and VE responses for each condition. However, it appears that the concepts of aerobic training are met when selecting rather low lifting loads. That is, a 4 mmol blood lactate concentration generated from 2.7% of 1RM for the HS and 12.8% of 1RM for the BP may have the potential to induce cardiovascular training effects over a 30 minute period (consisting of 15 minutes each of UL and LL work). Cardiovascular training adaptations have certainly been implicated with circuit resistance training modalities applying lifting loads of 40% 1RM providing a more whole-body type of conditioning (Gotshalk et al., 2004). Steele et al. (2012) further confirmed that lifting a weight to momentary muscular failure likewise improved cardiovascular variables. Thus, from an objective standpoint, a variety of resistance training modalities appear capable of achieving cardiorespiratory benefits. The STe loads used in our research are generally not thought to promote gains in strength, but resistance training guidelines have been reconsidered in terms of the unlikelihood of a single position statement for all (Carpinelli et al., 2004).

Post-exercise  $\text{VO}_2$  was significantly higher than the RMR at all times throughout recovery in both sessions, with significantly higher  $\text{VO}_2$  found only in Ee within the first 5 minutes of recovery (Table 4). The values of the present study concur

with several studies indicating that recovery  $\text{VO}_2$  remained significantly higher than the RMR for at least 30 minutes after exercise (Drummond et al., 2005; Foureux et al., 2006; Hackney et al., 2008; Schuenke et al., 2002). Volume and intensity are the variables that most influence post-exercise  $\text{VO}_2$  (Meirelles and Gomes, 2004), with the level of physical activity and gender of the subjects also influencing the magnitude and duration of the changes (Borsheim and Bahr, 2003; Warren et al., 2009). Braun et al. (2005) observed that circuit STe induced higher  $\text{VO}_2$  during the first 30 minutes of recovery compared to treadmill exercise, and there were no significant differences between 30 and 60 minutes after exercise. It is noteworthy that the Braun et al.'s (2005) study used different loads and sessions: the STe session was performed first and in a circuit format; and the Ee session was performed after, with an intensity matched to the STe session.

Our study was not without limitations. Although the sample size was small ( $n=8$ ) and the statistical power was not optimal (80%), the repeated measures design appeared sufficient to analyse differences between STe and Ee sessions. Moreover, standardising exercise intensity between STe and Ee is quite problematic, not only because of likely physiological and metabolic differences between muscle contractions at % $\text{VO}_2$  versus %1RM, but also because as many as 25 lactate threshold concepts have been identified (Faude et al., 2009), as well as several gas exchange thresholds (Meyer et al., 2005); thus, our selection of a "threshold" may be subjective. However, this study can be the first step for future research to find the best way to control the intensity of aerobic exercise or strength exercise in order to make them comparable.

## Conclusion

When exercise volume, intensity and loads were relativised in a predominantly aerobic (threshold) regime, the exercises performed with ergometers compared to traditional strength training exercises provoked somewhat similar responses, so that the load/intensity, and not the material/equipment used for the execution of an exercise, were variables that best influenced oxygen uptake. It can be concluded that strength exercises can also be used to improve oxygen uptake and cardiovascular fitness in the same way aerobic exercises do.

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