Comparison of Acute Cardiorespiratory Responses in Women Engaged in Local Muscle Endurance vs. High Load Strength Training

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¹Human Performance Nucleus, Physical Education Course, College of Health Science, Methodist University of Piracicaba (UNIMEP), São Paulo, Brazil, ²College of Exact Sciences and Nature – UNIMEP - São Paulo – Brazil ³Faculty of Applied Sciences, State University of Campinas (UNICAMP), Limeira, São Paulo, Brazil.

ABSTRACT

Simões RA, Gonelli PRG, Celante GS, Sindorf MAG, Souza TMF, Montebelo MIL, Borin JP, Cesar MC. Comparison of Acute Cardiorespiratory Responses in Women Engaged in Local Muscle Endurance vs. High Load Strength Training. JEPonline 2011;14(4):106-119. This study examined the acute cardiorespiratory responses of strength training protocols in trained women. Twenty-two subjects performed cardiorespiratory, 1RM tests, and two sessions of strength training with distinct load intensities. The strength protocols were local muscle endurance (LME, 3 sets of 15 to 20 RM repetitions at 50% of 1 RM and a 1 min rest interval between sets) and high load strength training (HLT, 3 sets of 3 to 5 RM repetitions, load of 90% of 1 RM and a 3 min rest interval between sets). At rest, there were no significant differences between the LME and HLT protocols for all variables. During the workout sessions, the LME protocol resulted in significantly (P≤0.01) higher VO₂, VCO₂, Vₑ, O₂ pulse, HR, Vₑ/VO₂, and Vₑ/VCO₂ responses as well as total volume of training vs. the HLT protocol. Although the LME protocol resulted in a higher cardiorespiratory overload versus the HLT protocol, it was too low to improve the cardiorespiratory fitness of young trained women.

Key Words: Cardiorespiratory, Muscular Strength, Oxygen Uptake
INTRODUCTION

A considerable number of researchers have investigated the effects of strength training on the maximal oxygen uptake (VO\textsubscript{2} max) and anaerobic threshold (AT) as determinants of cardiorespiratory fitness. While numerous studies did not obtain improvement in either of these indices (8,13,15,20,31), there are other resistance training studies that did show improvement in cardiorespiratory fitness. The authors of these studies used men as their subjects (14,19,25,26,34,36) while only two of the studies used women as subjects (35,36).

The intensity of effort parameters for improving cardiorespiratory fitness are well defined. The load of aerobic training should reach 50% to 85% of VO\textsubscript{2} max and/or 55% to 90% of the maximal heart rate (HR max) (3). Anaerobic threshold also corresponds to an intensity of effort that can be used in training to improve cardiorespiratory fitness (6).

Strength training programs can be classified according to the number of repetitions, load, and rest interval between sets. Heavy loads of 1 to 6 repetition maximum (RM) with long rest intervals characterize strength and power training (HLT). Hypertrophy strength training is characterized by moderate to heavy loads, 6 to 12 RM with moderate to short rest intervals, while high repetitions and short rest intervals constitute local muscle endurance training (LME). Each of these types of strength training may stress different energy systems for ATP resynthesis. Strength and power training (HLT) overload the ATP-PC system. Hypertrophy and strength training uses the ATP-PC system and anaerobic glycolysis. Local muscle endurance training (LME) is more dependent on the contribution of energy from aerobic metabolism (24).

In order to assess the aerobic and/or metabolic overload of strength training protocols, researchers have evaluated the acute responses of the cardiorespiratory system during strength training sessions (1,7,10,12,18,21,22,28,29,38). The studies that used low intensity resistance circuit training showed a cardiorespiratory response at approximately 50% of VO\textsubscript{2} max and/or 55 to 65% of HR max in men (18, 38) and women (38). Two studies evaluated acute cardiorespiratory responses of hypertrophy training sessions in young trained women and reported low energetic demand (7, 21). This low aerobic overload was also reported in LME sessions in older adults of both sexes (29), trained young men (10), and untrained young adults of both sexes (28). Alcaraz et al. (1) investigated the acute cardiovascular response of HLT protocols in trained men and reported values of approximately 60% of subjects expected HR max (220-age).

Botelho et al. (10) examined the effect of LME protocols on the cardiorespiratory system of young male subjects during the bench press exercise (10). Other researchers used a single set protocol (28,29). The only research that examined HLT protocols (1) measured only the HR as a parameter to determine the acute cardiovascular response during strength training. Therefore, although it has been reported that LME protocols involve a higher aerobic energy contribution (24), and HLT protocols could have an aerobic overload enough to reach the intensity needed to improve cardiorespiratory fitness (1), there were no studies found that measured acute cardiopulmonary responses to multiple sets of LME and HLT training sessions and, then, compared the responses of the distinct protocols in the same subjects, especially in young trained women as subjects.

The purpose of this study was two-fold: (1) to compare the subjects’ cardiorespiratory responses during two different strength training protocols (LME and HLT); and (2) to compare to the same variables at maximum intensity of effort and at AT intensity of effort in order to verify if one or both
strength training protocols achieved the minimum necessary aerobic overload to improve the subjects’ aerobic fitness.

METHODS

Subjects
Twenty-two healthy young women (22.9 ± 3.4 yrs, 58.1 ± 6.3 kg, 165.0 ± 8.0 cm, 21.34 ± 1.36 kg/m²) were recruited from the University and surrounding community. The subjects had experience with 1RM, cardiorespiratory testing, and were engaged in strength training for a minimum of 6 months in accordance with the guidelines of the American College Sports Medicine (4,9). Each subject completed a health questionnaire at the beginning of the experimental protocol to prevent adverse reactions to the tests and training. After the explanation of the project, the subjects signed a written informed consent. This study was approved by the Ethics in Research Committee of the Methodist University of Piracicaba.

Procedures
The experimental protocol was carried out in four non-consecutive days, with a 48 to 72 hr break between sessions. Evaluations and preliminary tests were carried out the first two days. The training sessions with cardiorespiratory monitoring were completed during the second two days. Refer to Figure 1 for the experimental design.

The cardiorespiratory tests established the physiologic variables at maximal and AT intensity as well as the aerobic fitness level of the subjects. The level of strength of the subjects, and the strength training loads were determined from the results obtained in the 1 RM test as follows: (1) Heavy load strength training (HLT), 3 sets of 3 to 5 RM at approximately 90% of 1 RM, 2 to 3 sec concentric / 3 to

![Figure 1. The Experimental Design.](image-url)
4 sec eccentric muscle action, 3 min rest interval between the sets and duration of approximately 79 min; and (2) Local muscle endurance (LME), 3 sets of 15 to 20 RM at approximately 50% of 1 RM, 1/2 sec concentric / 2 to 3 sec eccentric muscle action, 1 min rest interval between the sets and duration of approximately 49 min. All subjects underwent the two distinct intensity strength training sessions with cardiorespiratory measures to compare aerobic overload between the two protocols and to determine what percent of the maximal and AT effort intensity they would reach during the strength training sessions.

In order to reproduce the same physiologic conditions during which they were training as well as between the assessments and strength training sessions, some control procedures were adopted. The subjects were explicitly instructed to maintain regular diet and not to perform any other physical exercise for at least 24 hrs before the evaluation and training sessions. One-half of the subjects started data collection doing, first, the LME training sessions and, then, the HLT. The other half proceeded the opposite way, featuring counterbalanced analyses model. Each subject performed the 1 RM test and strength training sessions at the same time of day, at which cardiorespiratory testing was performed. Temperature in the Strength Training Room was registered prior to the 1 RM tests and during the strength training sessions. Training was conducted only when temperature was between 20°C and 26°C. All procedures were carried out by the same evaluators.

**Anthropometric Measurements**

The subjects’ body mass was measured by mechanical balance (Welmy®). Height was determined using a stadiometer (Alturaexata®), and the BMI was calculated by dividing the body mass by the square of the subjects’ height.

**Cardiorespiratory Capacity Measurement**

The subjects’ cardiorespiratory system was evaluated by way of an Inbrasport ATL® treadmill in which an incremental-load continuous protocol was used. The initial workload was set at 2.5 mph (3 min) and increased by 0.6 mph every minute up to 6.2 mph, followed by 2.5% inclination per minute until exhaustion (13,36). All tests were continually monitored (ERGO-S DIXTAL®) by electrocardiograph (ECG).

Oxygen uptake (VO₂), carbon dioxide output (VCO₂), and expired ventilation (Vₑ) were measured directly using a Medical Graphics® VO2000 metabolic gas analyzer. The metabolic system was calibrated prior to each test in agreement with the manufacturer's recommendations. VO₂ max was determined according to previously described criteria (13,36). The anaerobic threshold was determined by ventilatory method (38). Heart rate (HR) during the treadmill test was monitored every 5 sec by a Polar Vantage NV® HR monitor strapped to the subject’s chest. Expired ventilation, O₂ pulse (VO₂/HR), and HR for the maximal exercise intensity and for AT intensity were determined.

**Muscle Strength Measurements**

All subjects underwent a 1 RM test, defined as the maximum amount of weight that could be lifted correctly once in a standard exercise (9,15). The tests were performed after a brief warm-up with static stretching and 10 repetitions with a low load on the bench press, latissimus pull down, and leg-press 45° (7,12). The order of the 1 RM tests was (24): bench press, leg-press 45°, latissimus pull-down, knee extension, hamstring curl, military press, lying barbell extension, and standing barbell curls. The 1 RM loads were determined according to previously described criteria (11,30).
Cardiorespiratory Measure Variables in Strength Training

The last phase in the experimental protocol consisted of monitoring the strength training sessions with distinct intensities. The training sessions consisted of the same exercises and followed the same criteria of order as the 1 RM test. On the training days, the subjects arrived at the laboratory and remained at rest for 30 min lying in the supine position. Then, the cardiorespiratory measures were taken at rest for 12 min. The first 2 min were discarded and an average of the 10 remaining minutes was used to determine the pre-training VO₂. Data collection was briefly interrupted to allow the subjects to consume to 200 ml of water, during which the telemetry system was also connected and, then, data collection was restarted.

After the end of the training sessions, the subjects returned to the laboratory, where they remained at rest, lying in supine position, until the VO₂ values returned to the pre test levels, thereby finishing the data collection. All the training sessions were timed to control the execution of each set/exercise and the total training time. The weight lifted and the number of repetition for each set were recorded and used to calculate the total volume of the training session. The volume was calculated by multiplying the number of repetitions by the weight lifted. Heart rate was monitored every 5 sec by a HR monitor. Oxygen uptake (VO₂), VCO₂, respiratory exchange ratio (RER), Vₑ, ventilatory equivalent for the oxygen (VEO₂), ventilatory equivalent for carbon dioxide (VECO₂), VO₂/HR, and HR were measured during the strength training sessions.

Data Analysis

The main cardiorespiratory variables, VO₂, Vₑ, VO₂/HR and HR were measured and compared before each strength training session to determine each subject’s pre training condition. These four variables plus RER, VECO₂, VEO₂ and total volume of training were also measured and compared after HLT and the LME strength training session to evaluate the impact of each protocol on the cardiorespiratory system. Moreover, VO₂, Vₑ, VO₂/HR, and HR were compared in percent terms to the same variables obtained at AT and at maximal effort of the cardiorespiratory test.

Statistical Analysis

Mean and standard deviation (±SD) for all variables were calculated. The sample power was set using the difference between the average of VO₂ in the strength training sessions, obtained from the paired t-test, to estimate the sample size with a power of 95% and significance smaller or equal to 5% (P≤0.05). Normal distribution of the data was checked by Shapiro-Wilk's test. Student's t-test was used for the comparison between the variables with normal distribution. Variables which did not fit into the normality criteria used the Wilcoxon test for comparison (39). An alpha level of P≤0.05 was set as the apriori level of significance. The data were processed with Excel, Bio Estat 5.0 and SPSS 18.0 software.

RESULTS

The sample power analysis indicated that the sample should have at least 11 subjects for a 95% power level and a significance level less or equal to 5%. Tables 1 and 2 show the results of the 1 RM and the cardiorespiratory tests.
Table 1. Mean ± standard deviation (SD), maximum and minimum value of the 1 RM test (n = 22).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>±SD</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench press (kg)</td>
<td>59.0</td>
<td>37.41</td>
<td>19.0</td>
<td>9.76</td>
</tr>
<tr>
<td>Leg-press 45º (kg)</td>
<td>300.0</td>
<td>220.45</td>
<td>130.0</td>
<td>47.96</td>
</tr>
<tr>
<td>Latissimus pull down (kg)</td>
<td>51.0</td>
<td>36.23</td>
<td>24.0</td>
<td>6.59</td>
</tr>
<tr>
<td>Knee extension (kg)</td>
<td>63.0</td>
<td>47.32</td>
<td>27.0</td>
<td>9.77</td>
</tr>
<tr>
<td>Military press (kg)</td>
<td>39.0</td>
<td>29.09</td>
<td>18.0</td>
<td>4.81</td>
</tr>
<tr>
<td>Hamstring curl (kg)</td>
<td>58.0</td>
<td>44.91</td>
<td>30.0</td>
<td>9.41</td>
</tr>
<tr>
<td>Lying barbell extension (kg)</td>
<td>34.0</td>
<td>20.14</td>
<td>12.0</td>
<td>6.03</td>
</tr>
<tr>
<td>Standing barbell curls (kg)</td>
<td>32.0</td>
<td>22.82</td>
<td>16.0</td>
<td>3.89</td>
</tr>
</tbody>
</table>

Table 2. Mean ± standard deviation (SD), minimum, and maximum value measured in the cardiorespiratory test (n = 22).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>±SD</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO2 max (mL·kg⁻¹·min⁻¹)</td>
<td>56.26</td>
<td>46.24</td>
<td>38.46</td>
<td>5.02</td>
</tr>
<tr>
<td>VE max (L·min⁻¹)</td>
<td>107.13</td>
<td>87.53</td>
<td>63.00</td>
<td>12.07</td>
</tr>
<tr>
<td>VO2 max/HR max (mL·beat)</td>
<td>19.97</td>
<td>14.00</td>
<td>9.66</td>
<td>2.36</td>
</tr>
<tr>
<td>HR max (beats·min⁻¹)</td>
<td>207.00</td>
<td>192.73</td>
<td>171.0</td>
<td>8.74</td>
</tr>
<tr>
<td>VO2 AT (mL·kg⁻¹·min⁻¹)</td>
<td>38.77</td>
<td>29.62</td>
<td>18.31</td>
<td>6.78</td>
</tr>
<tr>
<td>VE AT (L·min⁻¹)</td>
<td>65.47</td>
<td>45.32</td>
<td>22.78</td>
<td>11.79</td>
</tr>
<tr>
<td>VO2 AT/HR AT (mL·beat)</td>
<td>19.28</td>
<td>11.23</td>
<td>7.60</td>
<td>2.49</td>
</tr>
<tr>
<td>HR AT (beats·min⁻¹)</td>
<td>183.00</td>
<td>152.82</td>
<td>118.00</td>
<td>19.02</td>
</tr>
</tbody>
</table>

VO2 max = maximal oxygen uptake; VE max = maximal pulmonary ventilation; VO2 max/HR max = maximal oxygen pulse; HR max = maximal heart rate; VO2 AT = oxygen uptake at anaerobic threshold; VE AT = pulmonary ventilation at anaerobic threshold; VO2 AT/HR AT = oxygen pulse at anaerobic threshold; HR AT = heart rate at anaerobic threshold.

Table 3 shows the results of the statistical comparison of the cardiopulmonary responses between the LME and HLT training sessions during in the resting condition. The results show no significant
differences in the measured variables. During recovery, after the training sessions the VO₂ returned to the resting values in less than 30 min in both protocols.

Table 3. Mean ± standard deviation (SD) and comparative statistical results of the cardiorespiratory responses between the LME and HLT sessions at rest (n = 22).

<table>
<thead>
<tr>
<th>Variables</th>
<th>LME</th>
<th>HLT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO₂ (mL·kg⁻¹·min⁻¹)ᵗ</td>
<td>3.55 ± 0.96</td>
<td>3.63 ± 0.69</td>
</tr>
<tr>
<td>Vₑ (L·min⁻¹)ʷ</td>
<td>6.31 ± 2.05</td>
<td>6.26 ± 1.07</td>
</tr>
<tr>
<td>VO₂/HR (mL·beat)ʷ</td>
<td>3.27 ± 1.53</td>
<td>3.10 ± 0.64</td>
</tr>
<tr>
<td>HR (beats·min⁻¹)ᵗ</td>
<td>65.8 ± 9.79</td>
<td>68.64 ± 11.35</td>
</tr>
</tbody>
</table>

LME = local muscle endurance; HLT = heavy load strength training; VO₂ = oxygen uptake; Vₑ = pulmonary ventilation; VO₂/HR = oxygen pulse; HR = heart rate; W = Wilcoxon test comparison; t = t-test comparison.

Statistical comparison of cardiorespiratory responses during the LME and HLT training sessions are shown in Table 4. The HLT training session resulted in significantly lower values for all of the cardiorespiratory responses except for RER. The total volume of training also demonstrated the same pattern where HLT reached 6,143.23 ± 1,251.01 kg, which was a significantly lower value than LME that reached 13,464.36 ± 2,710.57 kg.

Table 4. Mean ± standard deviation (SD) and comparative statistical results of cardiorespiratory and total volume variables between the LME and HLT training sessions (n = 22).

<table>
<thead>
<tr>
<th>Variables</th>
<th>LME</th>
<th>HLT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO₂ (L·min⁻¹)ʷ</td>
<td>0.56 ± 0.17**</td>
<td>0.38 ± 0.07</td>
</tr>
<tr>
<td>VCO₂ (L·min⁻¹)ʷ</td>
<td>0.67 ± 0.20**</td>
<td>0.44 ± 0.46</td>
</tr>
<tr>
<td>RERᵗ</td>
<td>1.25 ± 0.17</td>
<td>1.22 ± 0.14</td>
</tr>
<tr>
<td>VₑO₂ᵗ</td>
<td>41.21 ± 5.79**</td>
<td>34.39 ± 4.39</td>
</tr>
<tr>
<td>VₑCO₂ᵗ</td>
<td>33.26 ± 3.24**</td>
<td>28.32 ± 2.50</td>
</tr>
</tbody>
</table>

LME = local muscle endurance; HLT = heavy load strength training; VO₂ = oxygen uptake; VCO₂ = carbon dioxide output; RER = respiratory exchanges ratio; VₑO₂ = ventilatory equivalence for oxygen; VₑCO₂ = ventilatory equivalence for the carbon dioxide; W = Wilcoxon test comparison; t = t-test comparison; ** = P≤0.01.

Table 5 shows the statistical comparison of the absolute values and the percentage relationship between the measured cardiorespiratory responses in the LME and HLT training sessions and the
same variables obtained in the maximal cardiorespiratory test. There is also the statistical comparison
between the LME and HLT training sessions showing that the LME presented significantly higher
results in all the physiological variables analyzed.

Table 5. Mean ± standard deviation (SD) and statistical comparison of absolute cardiorespiratory
responses during the LME and HLT training sessions, and in relation to the percent of the
maximum exercise intensity and the AT exercise intensity (n = 22).

<table>
<thead>
<tr>
<th>Variables</th>
<th>LME</th>
<th>HLT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO₂ (mL·kg⁻¹·min⁻¹)</td>
<td>9.42 ± 2.50**</td>
<td>6.51 ± 1.12</td>
</tr>
<tr>
<td>VO₂ %max (%)</td>
<td>20.35 ± 4.52**</td>
<td>14.10 ± 2.05</td>
</tr>
<tr>
<td>VO₂ %AT (%)</td>
<td>32.71 ± 7.95**</td>
<td>22.75 ± 4.87</td>
</tr>
<tr>
<td>VE (L·min⁻¹)</td>
<td>22.62 ± 6.75**</td>
<td>12.86 ± 1.78</td>
</tr>
<tr>
<td>VE %max (%)</td>
<td>27.84 ± 10.51**</td>
<td>15.62 ± 2.55</td>
</tr>
<tr>
<td>VE %AT (%)</td>
<td>56.27 ± 21.71**</td>
<td>31.83 ± 9.53</td>
</tr>
<tr>
<td>VO₂/HR (mL·beat)</td>
<td>4.98 ± 0.20**</td>
<td>4.06 ± 0.90</td>
</tr>
<tr>
<td>VO₂/HR %max (%)</td>
<td>35.08 ± 8.39**</td>
<td>29.12 ± 4.78</td>
</tr>
<tr>
<td>VO₂/HR %AT (%)</td>
<td>43.84 ± 8.66**</td>
<td>36.44 ± 6.49</td>
</tr>
<tr>
<td>HR (beats·min⁻¹)</td>
<td>112.83 ± 14.13**</td>
<td>94.57 ± 14.79</td>
</tr>
<tr>
<td>HR %max (%)</td>
<td>58.51 ± 6.36**</td>
<td>48.90 ± 5.90</td>
</tr>
<tr>
<td>HR %AT (%)</td>
<td>47.66 ± 11.41**</td>
<td>62.65 ± 12.01</td>
</tr>
</tbody>
</table>

LME = local muscle endurance; HLT = heavy load strength training; VO₂ = oxygen uptake; VO₂ %max = oxygen uptake in relation to the percent of maximum intensity of the exercise; VO₂ %AT = oxygen uptake in relation to the percent of anaerobic threshold intensity of the exercise; VE = pulmonary ventilation; VE %max = pulmonary ventilation in relation to the percent of maximum intensity of the exercise; VE %AT = pulmonary ventilation in relation to the percent of anaerobic threshold intensity of the exercise; VO₂/HR = oxygen pulse; VO₂/HR %max = oxygen pulse in relation to the percent of maximum intensity of the exercise; VO₂/HR %AT = O₂ pulse in relation to the percent of anaerobic threshold intensity of the exercise; HR = heart rate; HR %max = heart rate in relation to the percent of maximum intensity of the exercise; HR %AT = heart rate in relation to the percent of anaerobic threshold intensity of the exercise; W = Wilcoxon test comparison; t = t-test comparison; ** = P≤0.01.

DISCUSSION

The sample size was twice the necessary value to reach a power level of 95% and a statistical
significance ≤5%. The comparison of the cardiorespiratory responses of the LME and HLT training
sessions measured at rest did not present significant differences. The pre-training conditions of the
subjects were similar before engaging in the training protocols. However, the comparative analysis of
the acute cardiorespiratory responses showed that the LME training resulted in a higher aerobic
overload than the HLT. The absolute and relative VO\textsubscript{2} to the body mass, V\textsubscript{CO\textsubscript{2}}, V\textsubscript{E}, VO\textsubscript{2}/HR, HR, V\textsubscript{E}O\textsubscript{2}, and V\textsubscript{E}CO\textsubscript{2} were significantly higher during the LME training, as well as the total volume of the
training. Only the RER response was similar in both groups with high values, showing a predominant
anaerobic characteristic in the training protocols.

When comparing the cardiorespiratory responses with the literature, there are certain difficulties in
doing so. For example, most of the studies were carried out with male subjects without consideration
for many of the physiologic variables analyzed in the present study. Wilmore et al. (38) reported on
the metabolic responses in 10 men and 20 women during strength training with 3 sets in 10 rounds of
30 sec with 15-sec breaks for recovery that resulted in 15 to 18 repetitions at 40% of 1 RM. The VO\textsubscript{2}
and HR were measured during training and compared to VO\textsubscript{2} max and HR max obtained in the
maximal cardiorespiratory test. The values of VO\textsubscript{2}, HR, VO\textsubscript{2} %max, and HR %max for the women
were 16.4 mL·kg\textsuperscript{-1}·min\textsuperscript{-1}, 152.1 beats·min\textsuperscript{-1}, 44.2%, and 81.60%, respectively. All of their responses
are much higher than what was found in the present study.

Phillips and Ziuraits (28,29) researched the caloric expenditure relative to the ACSM recommended
training of 1 set of 15 repetitions with a 2 min rest between 8 exercises. Their studies were carried out
with men and women subjects, including both young and elderly subjects. Considering the small
number of subjects (n = 6) and the differences in the number of sets, rest intervals between sets and
the total time of training which was 24 min (which is certainly less than the 49 and 76 min sessions in
the present study), the VO\textsubscript{2} values presented by the young women (28) were slightly higher than the
LME training of the current study at 0.65 L·min\textsuperscript{-1} and yet, similar to the study of elderly women (29) at
0.57 L·min\textsuperscript{-1}.

Binzen et al. (7) examined on the metabolic responses of 20 young women engaged in a training
program consisting of 9 exercises (3 sets of 10 repetitions, 70% of 1 RM with 60 sec rest between
each set with a total of 45 min for each exercise session). They reported an average VO\textsubscript{2} of 0.68
L·min\textsuperscript{-1}, which is essentially the same as the response reported in the present study. Although there
are only three studies with younger women (7,21,28) for comparison, within the same parameters, the
results of this study are similar to the findings in the literature, especially in relation to LME training.
However, in regards to the HLT protocol, the only study found was in men in which only HR was
monitored (1).

The LME protocol resulted in higher cardiorespiratory responses than did the HLT protocol, but if
compared the variables, specially VO\textsubscript{2} and HR, with other forms of exercise such as walking (16),
aerobic gymnastics and treadmill running (27), pedaling on a cycle ergometer on a submaximum load
(5,32), pump, step, body combat, and spinning (33), and jump fit classes (17), it is obvious that the
intensity of the both protocols is very low. For example, the mean VO\textsubscript{2} %max of 20.4 for LME is
functionally one-fourth of the subjects’ VO\textsubscript{2} max (which is significantly greater than the VO\textsubscript{2} %max for
HLT). The same can be observed with the VO\textsubscript{2}/HR response (i.e., O\textsubscript{2} pulse, which correlates with
stroke volume). The LME resulted in a slightly higher SV versus the HLT protocol, but certainly with
lower values than found during aerobic gymnastic and treadmill walk (16) and pedaling on a cycle
ergometer at a submaximum load (5,33). Overall, the low O\textsubscript{2} pulse values suggest that the resistance
training resulted in a disproportionately higher HR response in relation to the energy costs of the
protocols.
The ventilatory equivalent ratio for oxygen is equal to $V_E$ divided by VO$_2$. During exercise when increasingly more energy is coming from anaerobic metabolism, there is an increase in lactic acid in the blood. To keep the blood from becoming too acidic, $V_E$ increases and helps in blowing off excess CO$_2$. At this point $V_E$ increases at a higher rate than oxygen consumption and thus this ratio ($V_E/VO_2$) begins to increase. The $V_E/VO_2$ is also used as an index of ventilatory efficiency. In regards to the LME versus HLT protocols (41.21 and 34.4, respectively, $P \leq 0.01$), the subjects’ lungs needed a higher $V_E$ for a given VO$_2$ (refer to Table 5).

When $V_E$O$_2$ (5,33) and VCO$_2$ (33) are compared to women pedaling on a cycle ergometer, it is clear that the ventilatory load is small. Thus, the training protocols of this study produced an exaggerated ventilatory response in relation to the metabolic demand (37). This is likely due to the anaerobic aspect of the researched protocols. In short, the aerobic overload in the strength training protocols is notably small, both in absolute and relative terms. Also, while it would be appropriate to refer to the VO$_2$ responses during the recovery (EPOC), the fact is that the VO$_2$ values returned to the pre-training session values in less than 30 min (38).

Faced with these comparisons and considering the minimum intensities of needed aerobic training to improve cardiorespiratory system, it is clear that evidence was not found with the strength training protocols researched in this paper. The ACSM (2,3) recommendation to improve aerobic fitness in individuals of low physical conditioning is 50% of VO$_2$ max or 60% of HR max (2) or 40 to 50% of the VO$_2$ reserve and 55 to 65% of HR max (3). The VO$_2$ was below these parameters, 20% and 12% of the VO$_2$ max for the LME and HLT, respectively. The break of 55 to 65% of the VO$_2$ of the subjects’ reserve should be between 27.0 to 31.0 mL·kg$^{-1}$·min$^{-1}$, which is about 3 times higher than the VO$_2$ of LME and 5 times greater than the HLT protocol.

On the other hand, the percent of HR max during LME reached the recommended parameters (59%) and the HLT session was near, 49% of the HR %max. Using the VO$_2$ values as a reference point shows that the HR response during the strength training is not proportional to the VO$_2$ and does not reflect the aerobic intensity of the exercise. The occlusion of blood flow in active tissues promotes increased adrenergic response, which associated with a low cardiac output response, provides a disproportionate increase in HR not corresponding to the metabolic intensity of the exercise (22,23). Additionally, this finding is in agreement with other studies (1,12,22,38).

The stimulus provided by aerobic training LME was certainly higher than the HLT, but both were too low to produce a cardiorespiratory overload sufficient to increase aerobic fitness. These results corroborate to a study done recently in our laboratory (13), which studied the effects of 12 wks of LME training with young women, with the same 8 exercises researched in the present study, 3 sets of 15 RM, and did not find changes in the VO$_2$ or in AT.

**CONCLUSIONS**

Although the local muscle endurance (LME) training protocol produced a significantly greater overload on the cardiorespiratory system than did the heavy load strength training (HLT) protocol, both protocols failed to reach a stimulus level to improve cardiorespiratory fitness in young trained women. Heart rate reached the necessary intensity during the protocols (2,3) to improve aerobic fitness as observed in others studies (1,18,38), but clearly the low VO$_2$ response during strength training would not result in aerobic improvements.
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