EXERCISE AND SPORTS MEDICINE CLINIC

ORIGINAL ARTICLE

ACUTE CARDIOPULMONARY RESPONSES OF WOMEN IN STRENGTH TRAINING

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ABSTRACT

Objective: To investigate the cardiopulmonary responses of one strength training session in young women. Method: Twenty-three women aged between 18 and 29 years participated in this study. All the volunteers were submitted to the following tests: cardiopulmonary and one-repetition maximum (1-RM). The strength training protocol had emphasis on muscular hypertrophy, three sets from eight to twelve repetitions under 70% of 1-RM, with a one minute thirty-second break between sets. During the training session, the cardiopulmonary variables were measured with a metabolic gas analyzer and a telemetry module. Results: The results of the oxygen consumption in the training session were from 8.43 ± 1.76 ml/kg/min and of the heart rate of 108.08 ± 15.26 bpm. The results of the oxygen consumption and of the heart rate in the training were lower ($p \leq 0.01$) than in the ventilatory threshold and in the oxygen consumption and the heart rate reserves. Conclusion: The obtained data show that the present protocol of strength training provided low overload to the cardiopulmonary system of young women.

Keywords: oxygen consumption, heart rate, pulmonary ventilation.

INTRODUCTION

Strength training has been subject of several studies, both for its direct relation with performance of many sports modalities and the proved benefits in the prevention and rehabilitation of musculoskeletal injuries and chronic diseases, as well as in training programs having health and quality of life as goal[1]. Moreover, we stress the positive effects of strength training in body composition and muscle strength development[2,3].

Concerning strength training with the purpose of muscular hypertrophy in young adults, the American College of Sports Medicine (ACSM)[1,4] recommends from eight to ten exercises, with one or more sets of eight to 12 repetitions at 70-85% of 1-RM with one to two-minute intervals between exercises. The cardiorespiratory and/or metabolic adjustments in strength training have been investigated in previous studies [5-8]; however, they have not been so in protocols such as the one for young women.

The cardiopulmonary test allows determining the maximum oxygen consumption (VO_{2max}) and the anaerobic threshold by ventilatory method (VT), these are important indices of cardiorespiratory functional limitation[9]. Percentage values of VO_{2max} (50-85%)[10] and of the maximum heart rate (55/65%-90%)[1] are used in the prescription of aerobic training intensities. The *American College of Sports Medicine*[1] proposes aerobic training intensities of 40-50% of the oxygen consumption reserve (VO_2) and heart rate (HR).

The present study had as aims to determine the cardiopulmonary responses of a strength training session in Young women, and to compare the oxygen consumption and heart rate values of the strength training session with values of ventilatory threshold and reserve to verify the cardiorespiratory overload in strength training proposed for young and healthy individuals[1,4].

METHODS

Approach

23 women aged between 18 and 29 years, healthy, non-smokers, under strength training for at least six months were studied. After having received explanation on the project, the volunteers signed the Free and Clarified Consent Form. The study was approved by the Ethics in Research Committee of the Methodist University of Piracicaba, protocol # 06/08.

The volunteers answered a questionnaire on the health history before the experimental protocol in an attempt to discard counter indications to the tests and training.

EXPERIMENTAL PROTOCOL

Tests protocol

After the clinical evaluation, the volunteers were submitted to a cardiopulmonary and muscular tests protocol with intervals of 48 to 72 hours. All tests were conducted in the Laboratory of Anthropometric Evaluation and Physical Exertion and in the Center of Quality of Life of the Physical Education Course of the Health Sciences School (FACIS) of the Methodist University of Piracicaba (UNIMEP).

Cardiopulmonary test

The volunteers were submitted to the cardiopulmonary test on treadmill (Inbrasport ATL®), with continuous incremental protocol with initial load of 4.0 km/h (three minutes), and increment of 1.0 km/h at every minute until 10.0 km/h; afterwards, increments of 2.5% of inclination/minute, until exhaustion[11].

The tests were continuously monitored in the MC5, AVF and V2 derivations, with electrocardiographic records at the end of each stage and in recovery.

Measurement of oxygen consumption, carbonic gas production and pulmonary ventilation was directly performed with a metabolic gas analyzer (VO2000 – Medical Graphics®). The maximum oxygen consumption and anaerobic threshold were determined by ventilatory method[9].

Heart rate during the treadmill test was measured at every 60 seconds through telemetry (Polar® Vantage NV) when the maximum heart rate (HR_{max}) and ventilator threshold (HRVT) were determined.

Tests of one repetition maximum

The 1-RM test was performed according to the following exercise order: bench press, leg-press 45º, back pull, quadriceps extension, back military press with barbell, back hamstrings flexion, high pulley overhead, triceps extension with barbell and barbell curl[12].

Measurement of the cardiopulmonary responses during strength training

After the initial tests, the volunteers performed one strength training session with monitoring of cardiopulmonary variables with a metabolic gas analyzer and telemetry (VO2000 – Medical Graphics®).

The pre-test measurements of the volunteers were determined after their recovery time at dorsal decubitus for 30 minutes. The cardiopulmonary measurements were taken during 12 minutes at rest, where the two first minutes of measurement were discarded, the oxygen consumption at rest determined (VO_2 rest) and heart rate at rest (HR rest) determined by the mean of the last ten minutes.

The reserve oxygen consumption (VO_2 reserve) and the reserve hear rate (HR reserve) were calculated by the equations[13].

$$VO_2 \text{ reserve} = 0.4 \times (VO_{2max} - VO_2 \text{ rest}) + VO_2 \text{ rest}$$

$$HR \text{ reserve} = 0.4 \times (HR_{max} - HR \text{ rest}) + HR \text{ rest}$$

Subsequently to the measurements at rest, the volunteers performed static stretching and then started training in the same eight exercises of the 1-RM tests. The strength training session had emphasis on muscular hypertrophy[1,4]: three sets of eight to 12 repetitions at 70% of 1-RM, with one-minute intervals and 30 seconds between sets and exercises. Specific warm-up with about 10 to 15% of 1-RM on the bench press, leg press 45º and back pull was performed prior to the beginning of the session.

During the strength training session, oxygen consumption (l/min and in ml/kg/min), carbon dioxide production (l/min), gas exchanges ratio, pulmonary ventilation (l/min), ventilatory equivalents for oxygen and carbon dioxide, oxygen pulse (ml/beat) and heart rate (bpm) through a metabolic gas analyzer and telemetry module were measured. After the end of the training session, the volunteers rested at dorsal decubitus, until the VO_2 values were similar to the pre-test ones.

RESULT ANALYSIS

Descriptive analysis of the results was performed for all variables. The results of the cardiopulmonary variables were expressed in absolute values, and the VO_2 and HR values as well in maximum percentage values, obtained in the cardiopulmonary test.

The values of oxygen consumption and heart rate during the strength training were compared with the ventilatory threshold and reserve of VO_2 and of HR values. The Shapiro-Wilk test was used for data normality and the Student's *t* test for comparison of results. Significance level adopted was of 5%.

RESULTS

Table 1 evidences the result of the cardiopulmonary test; table 2 presents the result of the 1-RM test and the load used in the training session, and table 3, the data of the cardiopulmonary variables in the strength training session. The duration of the strength training session was in average of 54 minutes and 43 seconds. In the training session, the VO_2 values were 18.41 ± 0.03% of VO_{2max}, and the HR values were 56.10 ± 0.06% of HR_{max}.

Table 1. Mean and standard deviation of the results of the cardiopulmonary test of the volunteers.

VO_{2max} (ml/kg/min)	45.94 ± 5.12
VO_2VT (ml/kg/min)	29.29 ± 6.81
HR_{max} (bpm)	192.78 ± 8.42
HRVT (bpm)	153.39 ± 17.66

VO_2max – maximum oxygen consumption; HRmax – maximum heart rate; VO_2VT – oxygen consumption in the ventilatory threshold; HRVT – heart rate in the ventilator threshold.

Table 2. Mean and standard deviation of the results of the 1-RM tests and training load of the volunteers.

Exercises	1-RM	Training load
Bench press (kg)	37.00 ± 9.74	26.17 ± 6.68
Leg 45º (kg)	219.00 ± 47.28	154.27 ± 3.80
Pulley (kg)	35.83 ± 6.72	25.35 ± 4.51
Knee Ext. (kg)	47.22 ± 9.55	33.12 ± 6.68
Military press. (kg)	28.87 ± 4.82	20.36 ± 3.29
Knee Flex. (kg)	44.78 ± 9.21	31.43 ± 6.44
Triceps (kg)	19.96 ± 5.96	14.09 ± 4.13
Curl (kg)	22.61 ± 3.93	15.97 ± 2.66

Bench press – bench press, free weight; Leg 45º – leg press 45º; Pulley – back pulley for back. machine; Knee ext. – knee extension. machine; Military press – back military press for shoulder. Free weight; Knee flex.– knee flexion. machine; Triceps – overhead triceps. Free weight; Curl – barbell curl, free weight.

Table 3. Mean and standard deviation of the cardiopulmonary variables of the strength training session.

VO_2 (L/min)	0,48 ± 0,1
VCO_2 (L/min)	0,57 ± 0,09
R	1,19 ± 0,15
O_2 pulse (ml/bat)	4,53 ± 0,97
VE (L/min)	18,04 ± 3,04
VEO_2	38,57 ± 5,46
$VECO_2$	32,72 ± 2,97

VO_2 – oxygen consumption; VCO_2 – carbon dioxide production; R – gas exchanges ratio; VE – pulmonary ventilation; VEO_2 – ventilatory equivalent for oxygen; VECO2 – ventilatory eqequivalent for carbon dioxide; Pulse O_2 – oxygen pulse.

The comparison of the VO_2 result during training presented values lower than the VO_2VT to the minimum of reserve VO_2 recommended for aerobic training[1] (figures 1 and 2). The HR was also lower in the training than in the HRVT and in the minimum reserve HR recommended for aerobic training[1] (figures 3 and 4). The VO_2 values returned to the pre-test values before 30 minutes of recovery.

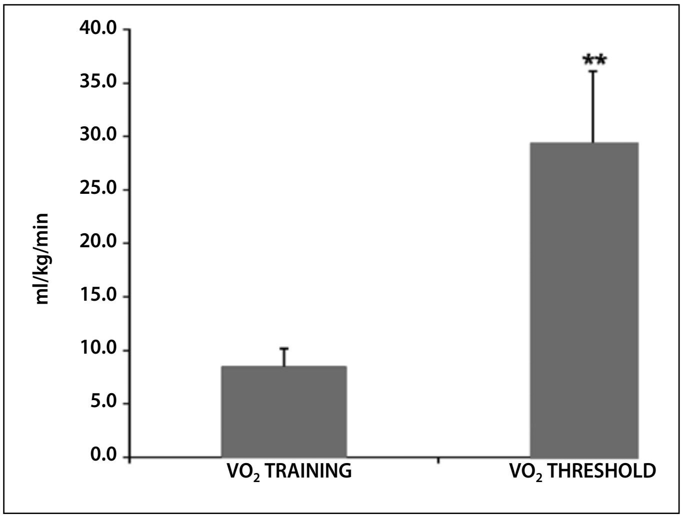

Figure 1. Comparison of oxygen consumption of the strength training session (VO_2 TRAINING) with the oxygen consumption of the ventilatory threshold (VO_2 THRESHOLD) of the volunteers. **P ≤ 0.01.

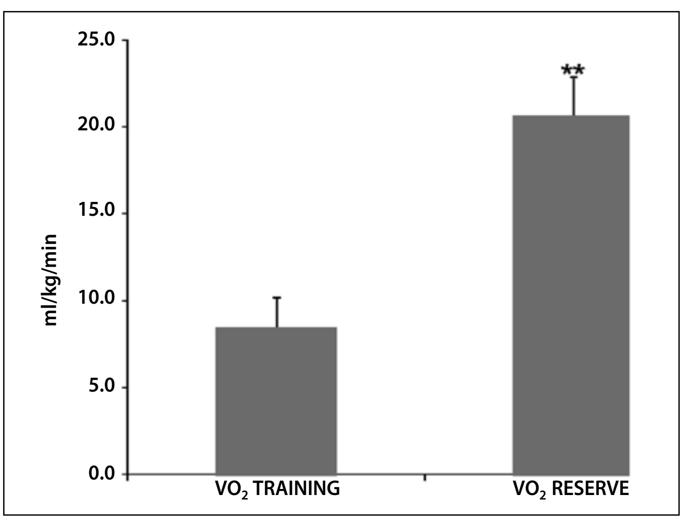

Figure 2. Comparison of the oxygen consumption of the strength training session (VO_2 TRAINING) with 40% of the reserve oxygen consumption (VO_2 RESERVE) of the volunteers.**P ≤ 0.01.

DISCUSSION

Few studies which investigate the acute cardiopulmonary responses to a strength training protocol in women have been reported in the literature; however, in the last years, strength training has been widely studied and recommended as prevention for chronic diseases[3,14], and the participation of women in strength training also remarkably increased [15,16]. Thus, it is important to acknowledge the cardiopulmonary responses of women in strength training.

The results obtained indicate that the VO_2 of strength training was low compared to the VO_{2max}, suggesting hence that this training provided small overload to the cardiorespiratory system. The VO_2 values in the training session were lower than in the VT and

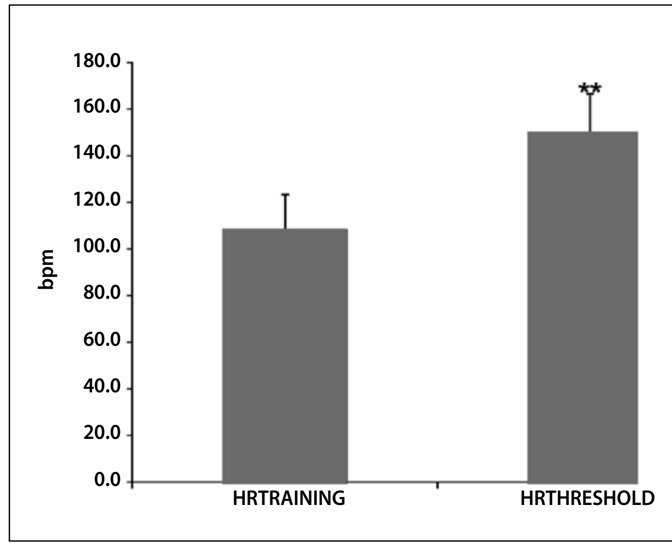

Figure 3. Comparison of the heart rate of the strength training session (HRTRAINING) with the heart rate of the ventilatory threshold (HRTHRESHOLD) of the volunteers.**P ≤ 0.01.

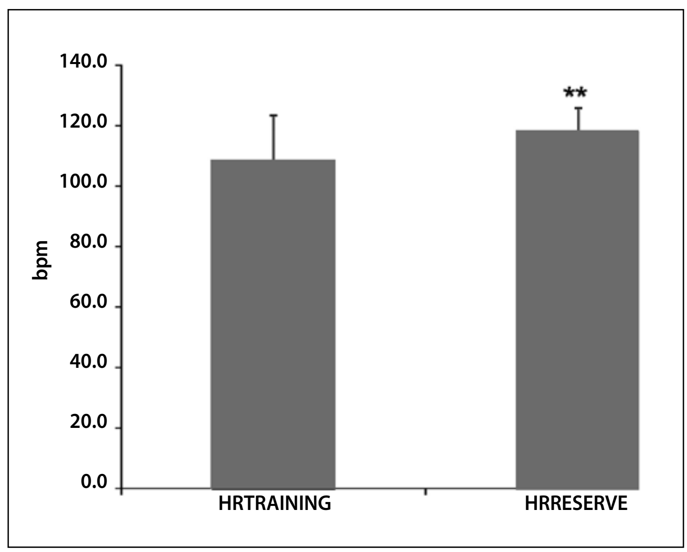

Figure 4. Comparison of the heart rate of the strength training session (HRTRAIINING) with 40% of the reserve heart rate (HRRESERVE) of the volunteers. **P ≤ 0.01.

the minimum recommendation of reserve VO_2 for aerobic training[1].

These results are in agreement with previous studies which investigated the adaptations to the cardiorespiratory system in women submitted to strength training, and found little or no improvement in cardiorespiratory fitness[2,17-20].

The majority of the studies found in the literature which investigated the cardiopulmonary responses in strength training [5,7,8] aimed at men or protocols different from the one used in the present study [6,21,22].

Bizen *et al.*[23] investigated the metabolic responses of a strength training in female individuals. The training consisted of three sets of tem repetitions, 60 seconds of interval between exercises, nine exercises at 70% 1-RM. The authors found VO_2 mean value of 0.68 L/min, which is higher than in the present study. Such fact seems to be justified due to the shorter interval between exercises, and no comparisons were made with the VT and the VO_2 minimum and reserve HR proposed for aerobic training[1].

The HR and VO_2 obtained in the present study were lower than in physical exercises modalities such as walking[24], aerobic gymnastics and treadmill running[25], cycling on a cycle ergometer at submaximal load[26,27], pump, step, body combat and spinning[28], as well as in jump fit classes[29].

The HR obtained in the present study was below the VT and reserve HR[1], despite the fact that in the maximum percentage values, it had been lower than the recommendation for aerobic training. However, the HR is not considered the most reliable parameter for controlling intensity of strength training, since there is no linear correlation between the HR and VO_2 in strength training[5,6].

In the present study, low O_2 pulse values have been found, these values were much lower than the ones found in aerobic gymnastics and treadmill running[25], walking[24], cycling on a cycle ergometer at submaximal load[26,28]. The low O_2 pulse of this study indicate that weight training led to excessive chronotropic response concerning the energetic demand, corroborating further studies which indicate that HR is not a suitable parameter to control intensity of strength training[5,6].

The pulmonary ventilation values in absolute values were lower than in women cycling on cycle ergometer[26], indicating that the ventilatory load was small; however, the values of ventilatory equivalents for oxygen[26,28] and carbon dioxide [28] were higher than the ones for women cycling on cycle ergometer at submaximal load, indicating hence that weight training led to exaggerated ventilator response concerning the metabolic demand[30].

The acute responses to strength training found in the present study corroborate the results by Dionne *et al.*[17], who investigated the adaptations to a strength training program with a protocol with three sets of ten repetitions in nine exercises with interval between sets of 60-90 seconds, for six months, and did not find alteration in the VO_{2max} in young women.

The results of this study indicate that the strength training proposed by the American College of Sports Medicine[1,4] for muscular hypertrophy and health maintenance did not promote sufficient stimulus for improvement in cardiorespiratory fitness of the young women studied here and aerobic training was necessary.

CONCLUSION

The results obtained show that the strength training protocol studied provided little aerobic overload for improvement of the cardiorespiratory system of trained young women. It can be concluded that the strength protocol proposed by the ACSM per se does not define alterations in the cardiorespiratory fitness.

ACKNOWLEDGEMENTS

The authors thank the Research Support Foundation of São Paulo State - FAPESP, for its grant, the Coordination for the Improvement of Higher Level Personnel – CAPES, for the Master's scholarships and the National Council for Scientific and Technological Development – CNPq, for the scientific initiation scholarships.

All authors have declared there is not any potential conflict of interests concerning this article.

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