

ORIGINAL SCIENTIFIC PAPER

High Load few Repetitions Exercise is better for the Cardiovascular System than low Load Many Repetitions Exercise

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Abstract

Blood pressure, pulse rate, and blood lactate concentration in response to resistance training are of critical significance for people, who could benefit from performing it, but to whom extreme blood pressure levels may be harmful. Traditionally high load training was held to cause an exaggerated blood pressure response but few recent studies challenged this. Since the published data is not unanimous, we examined whether longer duration with low load or high load in shorter duration would be favorable to heart rate, blood pressure, double product, and lactate levels in a group of healthy young people. Twenty-three young students performed twice, a week apart, a sequence of four sets of an exercise, once with 20 repetitions of 50% of maximal resistance of 1 Repetition Maximum and once with 10 repetitions of 75% of 1 Repetition Maximum. Heart rate was measured continuously while blood pressure and blood lactate levels were measured before exercise and after the conclusion of each set. Heart rate, blood pressure, and blood lactate levels increased significantly more following the 20, lower load repetition sets compared to the higher load 10 repetition sets. We conclude that high load low repetition exercise is less demanding on the cardiovascular system compared to lower load high repetition exercise, which should be considered in prescribing physical activity to older beginners and cardiac rehabilitation patients.

Keywords: resistance training, cardiac rehabilitation, blood pressure, blood lactate

Introduction

Blood pressure (BP), heart rate (HR) and lactate (La) concentration in peripheral blood in response to resistance training (RT) are of critical significance in certain people, such as older beginners and cardiac rehabilitation patients, who could benefit from performing it, but to whom extreme BP levels may be harmful.

RT improves strength and power of action (Garcia et al., 2016; Haskell et al., 2007) and is recommended to the general population as a preventive measure against cardiovascular disease (CVD). It is recommended also to the group of people already diagnosed with CVD as an adjunct to pharmacological treatment (Bjarnason-Wehrens et al., 2004; Sharman, La Gerche, & Coombes, 2015) and to aerobic training in patients with high BP (Carpio-Rivera, Moncada-Jiménez, Salazar-Rojas, & Solera-Herrera, 2016; Pescatello et al., 2004). Beyond these, RT is known to slow age-related deterioration on both muscular and neuronal levels (Rubenstein, 2006; Chen et al., 2015).

The efficacy of RT for the achievement of different goals depends on the selection and combination of various elements of RT (Bird, Tarpenning, & Marino, 2005) and the consequences of the various clinical conditions in which one should apply each combination (Garber et al., 2011). The balance between high-load low-repetition and low-load high-repetition RT depends on the condition of the subject in question, i.e. whether it is a young athlete who begins a training program or a person after myocardial infarction who seeks rehabilitation



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E. Weissblueth Tel Hai Academic College, School of Physical Education, Upper Galilee, 1220800, Israel E-mail: eyalwei@telhai.ac.il (Sardeli et al., 2017; American College of Sports Medicine, 2009). Related issues to the subject of load vs repetition are post-exercise hypotension and the cumulative effect on arterial stiffness (Cavalcante et al., 2015; Li et al., 2015).

RT with high repetitions and low load affects the cardiovascular system, and muscle endurance (Campos et al., 2002) whereas high load low repetition increases muscle power (Willardson, 2006). A prime concern in people with a cardiac deficit is the elevation of BP (de Vos et al., 2008; MacDougall, Tuxen, Sale, Moroz, & Sutton, 1985; Pedersen & Saltin, 2006; Perk et al., 2012), thus the recommendations for healthy old adults was to use low load high repetition sets of exercises (American College of Sports Medicine, 2009; Pescatello, MacDonald, Lamberti, & Johnson, 2015), in order to refrain from the Valsalva maneuver, known to be taken during high load exercise, which elevates BP (Narloch & Brandstater, 1995). Quite to the contrary, some more recent studies indicated that longer duration of effort, rather than its intensity elevates BP more pronounced (Borde, Hortobágyi, & Granacher, 2015; Gjovaag, Hjelmeland, Ovgard, Vikne, & Mirtaheri, 2016; Lamotte, Niset, & van de Borne, 2005; Palatini et al., 1989), which is critical to cardiac patients (Wise & Patrick, 2011). Additionally, others found higher blood La levels after long-duration exercise (Aguiar et al., 2018). Whereas for young and healthy individuals this is immaterial, for cardiac patients it may become detrimental.

Since the published data is not unanimous, we aimed at examining whether a longer duration with low load would be favorable to HR, BP, double product, and La levels in a group of 23 healthy young people.

Methods

Participants

All participants were students for physical education, ages 20-32, who were thoroughly interviewed to verify the lack of any health problems of the cardiovascular and musculoskeletal systems. All participants signed a form of informed consent and health declaration. Table 1 depicts the details of background data on the participants. The Ethics Committee for Studies in Human Subjects of the Academic College (7-2020) approved the study in advance. Each participant voluntarily provided written informed consent before participating.

Table 1. Physical characteristics of the participants in the study (N=23)

	Mean±SD
Age	24.9±3.3
Hight (cm)	172.4±9.9
Weight (kg)	69.6±10.9
Fat percentage	20.8±7.0
Fat mass (kg)	28.8±5.0
Lean Body Weight (kg)	55.2±10.4
BMI (kg/m2)	23.3±2.6

Measures

The test was done on a training device for knee-push (RS-1401 Leg Extension, HOIST[®] Fitness, San Diego, California, USA), leaving the arms to be crossed over the chest as was done in previous studies (Gjovaag et al., 2016). One Repetition Maximum (RM1) was determined for each subject during 10 repetitions with maximum weight (Desgorces, Berthelot, Dietrich, & Testa, 2010). To scale a participant's personal test load, RM10 (low repetitions, high load) was assumed to be 75% of their RM1 load while RM20 (high repetitions, low load) was 50%. Blood La was measured from capillary blood with EKF Diagnostic Mobile quick lactate-meter. Systolic and diastolic BP (SBP & DBP, respectively) was measured using a non-invasive continuous meter PROBP 3400 WSUREBP made by Welch Allyn. HR was measured using an electronic HR monitor (Polar H7 watch/strap with Polar Beat application). Weight was measured by a scale endowed with a body composition analyzer (Tanita DC-360 – Tanita Corporation).

Design and Procedures

The RM10 test and RM20 tests were conducted a week apart. In each test, 4 sets of exercises were carried out. For RM10 and RM20, at the onset of each set, participants performed a 10-times leg-push against 75% of RM1 load or 20 leg-push against 50% of RM1 load respectively. The resting interval between sets was 3.5 min. The order of the two events was defined randomly. Measurements were taken before the start (R), immediately after each set (E1, E2, E3 and E4) and at 3 (except La to provide for ethical limitations) and 5 minutes after the conclusion of the total test (R3, R5 respective-



Legend: BP=blood pressure; HR=heart rate; La=serum lactate level. Conditions: R-Rest, E1-1st set, E2-2nd set, E3-3rd set, E4-4th set, R3, R5-3 and 5 min into recovery respectively

FIGURE 1. Exercise and testing schedule as applied to participants.

Once with RM20 for four times 20 repetitions and once with RM10 for four times 10 repetitions.

ly). Figure 1 depicts the order of events. Mean arterial blood pressure (MBP) was calculated as MBP=DBP+[SBP-DBP]/3. Rate-pressure product (RPP) was calculated as RPP=HR×SBP. After each testing event, participants reported their subjective fatigue on a traditional Borg scale.

Statistical analysis

All parameters in this study were continuous. To examine the effect of the duration of repetitions on the physiological indices – BP, HR, and La, a two-way analysis of variance was performed with repeated measurements in a 2 x 2 x 7 array. To examine the difference between RM10 and RM20, a paired t-test procedure was employed. Data were imported into JASP statistical software version 0.12.2 for analysis, which was used for all statistical analyses and the significance level was set at 2-tailed, $\alpha \leq 0.05$.

Results

A two-way within-subjects ANOVA was conducted to compare the effect of exercise on SBP for each of 4 sets and

3 and 5 minutes into recovery conditions. Normality checks were carried out on the residuals which were approximately normally distributed thus it was used with a Greenhouse-Geisser correction. Figure 2 shows that there was a significant main effect of exercise sets on SBP (F(3.28, 72.151)=27.66, p<0.001, η 2=0.268). Bonferroni post-hoc tests showed that during RM10 participants raised their SBP significantly more during exercise sets (M range=128.7-131.1 mmHg; SD range=13.6-16.2) compared to that during rest and recovery (M range=119.8-122.3 mmHg; SD range=11.8-15.0). During RM20, participants raised their SBP significantly more during exercise sets (M range=137.7-140.2 mmHg; SD range=14.0-18.1) compared to that during rest and recovery (M range=121.6-125.8 mmHg; SD range=11.0-14.3). Posthoc comparing SBP levels in RM10 and in RM20 revealed a significant difference (F(1,22)=5.119, p=0.034, η2=0.063). During RM20 exercises and following it at each set, SBP was significantly (P<0.05) higher than during and following RM10 exercises.





The same statistical procedures were carried on DBP together with a paired t-test for individual sets. Figure 3 indicates that DBP followed the same pattern as SBP. However, there was a significant difference in DBP only after E3 in the RM20 exercise (M=81.6 mmHg, SD=4.9) compared to the RM10 exercise (M=76.9 mmHg, SD=5.7), t(22)=-2.656, p=0.014 and after the E4 set in the RM20 exercise (M=81.6 mmHg, SD=4.9) compared to that in the RM10 exercise (M=77.9 mmHg, SD=4.8), t(22)=-3.485, p=0.002.





Comparing HR levels across various conditions and between RM20 and RM10 with the same statistical procedures revealed statistically significant differences. Figure 4 shows that there was a significant main effect of exercise sets on HR (F(2,40)=191.5 p<0.001, η 2=0.764). Bonferroni post-hoc tests showed that during RM10 participants raised their HR significantly more during exercise sets (M range=113-119 beats per minute (bpm); SD range=17.3-20.4) compared to that during rest and recovery (M range=78–83 bpm; SD range=17.6-19.4). During RM20, participants raised their HR significantly more during exercise sets (M range=130-142 bpm; SD range=16.0-20.4) compared to that during rest and recovery (M range=79-91 bpm; SD range=1.2-19.4). Posthoc comparing HR levels in RM10 and in RM20 revealed a significant difference (F(1,20)=41.185, p<0.001, η 2=0.07). During RM20 exercises and following it at each set, HR was significantly (P<0.001) higher than during and following RM10 exercises.



FIGURE 4. Heart rate during exercise schedule as applied to participants, once with RM20 for four times 20 repetitions (filled circles) and once with RM10 for four times 10 repetitions (open circles)

Figure 5 exhibits blood La level during the two exercise schedules. La levels across conditions and between RM20 and RM10 were compared and showed statistically significant differences. There was a significant main effect of exercise sets on La (F(2.231,49.086)=84.142, p<0.001, η 2=0.501). Bonferroni post-hoc tests showed that during RM10 and RM20 blood La levels of the participants increased significantly in each set compared with the previous one (p<0.01). Post-hoc

comparing blood La levels in RM10 and RM20 revealed that during RM20 exercises at each set, it was significantly (F(1,22)=29.798, p<0.001, η 2=0.144) higher than during RM10 exercises. Furthermore, unlike hemodynamic parameters, which returned to initial levels after the sets, blood La continued rising and even after the conclusion of the session remained significantly higher (t(22)=-10.271, p<0.001) compared to the beginning of the session.



FIGURE 5. Blood lactate levels during exercise schedule as applied to a group of 23 young people, once with RM50 for four times 20 repetitions [full dots] and once with RM75 for four times 10 repetitions [open circles]

Discussion

The current study aimed at comparing the cardiovascular and metabolic responses during exercise between two different protocols in healthy young people, to address the issue of which of the two would be projected to benefit older people with CVD, for whom increased BP and La levels can be detrimental. It was previously defined that RT with a high number of repetitions (Campos et al., 2002; de Vos et al., 2008; Li et al., 2015; Pedersen & Saltin, 2006; Willardson, 2006) with low to moderate load affects the cardiovascular system, and muscle endurance (Campos et al., 2002) whereas RT with high load and lower number of repetitions (Bird et al., 2005; Chen et al., 2015; Garber et al., 2011; Rubenstein, 2006; Sardeli et

al., 2017) increases muscle power (Willardson, 2006). When planning a training program it is accepted that for improving muscle power, lean body mass and to lower the cardiac load one should aim at 70% of the tested repetition maximum of a person, called RM1 (American College of Sports Medicine, 2009; Garber et al., 2011). A prime concern in this planning process for people with a known cardiac deficit is the elevation of BP during the effort. It is thus advised that performing 15-20 repetitions with 40%-60% of RM1 is expected to elevate BP to a moderate extent (de Vos et al., 2008; Pedersen & Saltin, 2006). Conversely, high load effort of 90%-95% of RM1 (which is defined as RM4) led to systolic pressures up to 320 mmHg (MacDougall et al., 1985). Consequently, the recommendations for improving muscle strength and muscle morphology in healthy old adults was to use low load high repetition sets of exercises (Bird et al., 2005; Chen et al., 2015; Garber et al., 2011; Pescatello et al., 2004; Rubenstein, 2006; Sardeli et al., 2017).

One of the observations underlying this sort of program was that this level of effort does not cause the person to use the Valsalva maneuver, which elevates BP (Narloch & Brandstater, 1995). Quite to the contrary, Borde et al. (2015) on their meta-analysis concluded with a recommendation of "a training volume of 2-3 sets per exercise, 7-9 repetitions per set, a training intensity from 51-69% of the RM1". They have not addressed the BP and HR issue when recommending sets of 6 sec for each repetition, whereas the previously accepted duration was 2-4 sec.

Furthermore, several studies indicated that a longer duration of effort, rather than its intensity elevates BP more pronounced (Castinheiras-Neto, Costa-Filho, & Farinatti, 2010; Gjovaag et al., 2016; Lamotte et al., 2005; Palatini et al., 1989). The latter concluded that the time under tension, i.e. the dynamic resistance exercise causes occlusion of blood vessels and depending on its intensity and duration, may lead to a compensatory baroreflex response, which is more common in exercises done until fatigue (Castinheiras-Neto et al., 2010). These conclusions are critical to cardiac patients since the current recommendation was to prefer longer exercise with a lighter load (Wise & Patrick, 2011).

The metabolic response to the same volume of exercise (high load short duration to low load long duration) with different durations showed higher blood La levels after long-du-

Acknowledgements

There are no acknowledgements.

Conflict of interest

The authors declare that there are no conflicts of interest.

Received: 07 March 2021 | Accepted: 02 May 2021 | Published: 01 February 2022

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ration exercise (Aguiar et al., 2018). Whereas for young and healthy individuals this is immaterial for cardiac patients, it may become detrimental.

Resistance training leads to reduced BP after exercise in the long run in both healthy people and those with CVD. Yet, it had to be verified whether the duration of effort or its degree would contribute to the elevation of HR, RPP, BP, and blood La levels during the exercise itself. As the lower load exercise was longer than the high load exercise it had to be tested whether the load is what increases these parameters, or the duration is the major determinant. Our findings, in agreement with several previous observations (Gjovaag et al., 2016), and opposed to others (Palatini et al., 1989), indicate that duration contributes more significantly than load. This conclusion also flies against the recommendations by several medical authorities (Garber et al., 2011).

The traditional view that led to the health organizations' recommendation held that high load effort entails more pronounced elevation of BP, especially through its associated need to perform the Valsalva maneuver. Few more recent studies found that contrary to the traditional view, longer duration exercises, despite involving lower load, led to a higher response of BP (Gjovaag et al., 2016; Lamotte et al., 2005). One study by Aguiar (2018) recorded blood La levels during and after various levels of load and duration and found that the highest levels were recorded following the longest exercise, even though the load was the lowest. This reflects the increased use of glycolytic products rather than ATP-CP, which in turn causes increased HR with its associated shorter diastole and lowered stroke volume, leading to an even more pronounced shift to glycolysis in a form of a "vicious cycle". Younger people overcome this within a short time of recovery but people with CVD are challenged by this sequence to the level of significant threat of ischemia.

In conclusion, the results of the current study can be projected to indicate that programs of rehabilitation of cardiac patients, as well as programs for older beginners responding to some medical wake-up call, should begin with relatively high load exercise that should be short. Only when these people adjust to the new schedule, the duration can be increased gradually and cautiously, with the same load or lower, to reach a sufficient level that would contribute to their general cardiovascular health.

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