Blood pressure response during resistance training of different work to rest ratio

Running title: Work to Rest Ratio on Blood Pressure

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ABSTRACT

Changes in the work to rest ratio (W:R) of resistance training protocols (RTP) (i.e. decreasing work and/or increasing rest) reduce the marked elevation in blood pressure (BP) that occurs during RTP execution. However, whether changes in RTP protocol structure without changing W:R can change BP responses to RTP is unknown. To investigate the effect of different structures of rest intervals and number of repetitions per set on BP response among RTP equated and nonequated for W:R, 20 normotensive participants (25±4 years) performed four different RTP of the leg extension exercise with the same work but different W:R structures. Two protocols followed the recommendations for cardiovascular disorders: I) HIGH W:R - 3x15:44s - 3x15:44s (setxreps:rest between sets), which has high W:R (45reps:88s) and II) LOW W:R - 3x15:88s - 3x15:88s, which has low W:R (45reps:176s). The other two protocols were W:R-equated to LOW W:R (45reps:176s): III) LOW W:R - 9x5:22s and IV) LOW W:R - 45x1:4s. Systolic BP ($\Delta$SBP) and diastolic BP ($\Delta$DBP) were assessed by finger photoplethysmography. There were significant main effects for $\Delta$SBP following RTP (p<0.05): HIGH W:R - 3x15:44s = LOW W:R - 3x15:88s > LOW W:R - 45x1:4s > LOW W:R - 9x5:22s (+87±5 and +84±5 vs. +61±4 vs. 57±4 mmHg). For $\Delta$DBP, there was a significant interaction between RTP and moment (p<0.05). Thus, HIGH W:R - 3x15:44 > LOW W:R - 3x15:88s > LOW W:R - 45x1:4s > LOW W:R - 9x5:22s (+53±5 vs. +49±5 vs. +44±4 vs. +38±3 mmHg). HIGH W:R - 3x15:44s produced the highest increase in $\Delta$DBP and LOW W:R - 9x5:22s produced the lowest increase in $\Delta$SBP and $\Delta$DBP. Our findings may help the development of RT protocols that may mitigate pressure peaks without changing important exercise variables (i.e. volume or duration).

**Keys Words:** Weight Lifting, Cardiovascular Response, Rest Interval, Rate of Perceived Exertion, Finger Photoplethysmography, Work to Rest Ratio –Equated
INTRODUCTION

Resistance training protocols (RTP) improve neuromuscular function in young, adult, and elderly individuals (1, 11), and a broad body of evidence has suggested that RTP contribute to reduce cardiovascular risk (1, 8, 37, 39). Thus, RTP has been recommended as a complementary mode of training for many cardiovascular diseases (4, 7, 23, 27, 32, 39). However, some studies have highlighted a marked elevation of blood pressure (BP) that occurs during RTP execution (2, 14, 15); which may exceed 300 mmHg for systolic BP (SBP) in healthy participants (26). Although rare, this exacerbated and abrupt increase in BP may trigger the disruption of preexisting aneurysms, causing subarachnoid hemorrhage (19) or aortic dissection (18). As cardiovascular events are the main cause of death worldwide (38) and even apparently healthy individuals may have high cardiovascular risk (18, 19), it is desirable to find ways to mitigate BP increase during RTP execution.

RTP can be defined based on weight lifted, number of sets, number of repetitions, and number and duration of the rest intervals between sets. All these parameters comprise the work to rest ratio (W:R) of the RTP, where the work is considered the total number of sets, repetitions and weight lifted (set x reps x weight lifted), and the rest is the total time of pause during the protocol (number of intervals x interval duration) (31). The W:R of the RTP may be an important marker of the exercise stress.

During the work phases of the RTP, BP increases progressively, while during the rest phases, it decreases (2, 22). RTP with shorter sets result in smaller BP increases, while those with shorter rest intervals produce greater BP increases (2, 14, 15, 22). Thus, traditionally, the ways to reduce BP during RTP are by increasing the duration of the rest between sets (22) or decreasing the number of repetitions in each set (2, 14, 15). However, these procedures also decrease W:R, which may result in lower training stimulus (31). Thus, it is important to manipulate RTP in such a way that reduce BP increment during its execution without changing W:R. For that, it is important to study the effects of manipulating the structure of RTP (organization of sets, repetitions, and intervals) without changing total W:R (which is called in this paper – equated) on BP responses during RTP execution.

Although previous RTP studies with same W:R (W:R-equated) demonstrated lower rating of perceived exertion (RPE) and metabolites accumulation when the sets are shorter and intervals are more frequent (12, 21), none of these studies investigated BP responses. RPE is related to central command activation (28), sympathovagal balance increase (35), and skeletal muscle metabolite production is related to chemoreflex and sympathetic activations (5, 24, 35). Since these responses are associated with BP increase during RTP execution, it is possible to
suppose that manipulations of the W:R structure also affect BP response during RTP execution.

In the light of these information, the aim of this study was to evaluate the influence of different schemes of rest intervals and number of repetitions per set among RTP with equated and non-equated W:R on BP response during RTP execution. The hypothesis is that the protocol with the highest W:R would produce the greatest BP increase; while among the protocols equated for W:R, BP increase would be smaller when sets are shorter, but this reduced effect would be blunted when interval duration is also shorter.

METHODS

Experimental approach to the problem

To test the hypothesis of the study, the participants were randomly submitted to four different RTP performed with same work but different W:R structures, as exposed in Figure 1. Two RTP followed the recommendations for patients with cardiovascular disorders (39) and differed in W:R: i) HIGH_W:R-3x15:44s, which has a greater W:R of 45reps:88s and ii) LOW_W:R-3x15:88s, which has a lower W:R of 45reps:176s. The other two RTP have the W:R-equated to the second protocol (i.e. 45reps:176s) but with different structures (organization of sets, repetitions, and intervals), presenting more sets with less repetitions: iii) LOW_W:R-9x5:22s and iv) LOW_W:R-45x1:4s. Each RTP was executed on separate occasions (48 hours apart) in a cross-over design with repeated measures. Beat by beat BP was continuously measured by finger photoplethysmography.

INSERT FIGURE 1 ABOUT HERE

Participants

Twenty young normotensive untrained non-obese volunteers participated in the study (10 males and 10 females). Their characteristics are shown in Table 1. Before enrollment, all the participants were informed of the risks, benefits, and objectives of the study, and signed an informed written consent approved by the Institution’s Ethics Committee.
Inclusion criteria to the study were: i) age ranged from 18 and 35 years; ii) normotension (SBP and diastolic BP – DBP - lower than 140 mmHg and 90 mmHg, respectively (7); iii) absence of obesity (body mass index below 30 kg/m²); and iv) untrained status (performance of less than 2h per week of physical activity). Exclusion criteria included i) presence of exercise contraindications (any known cardiovascular, metabolic or musculoskeletal disease) and ii) use of medication that could affect cardiovascular function.

**Familiarization and Experimental Sessions**

Compliance with the study criteria was evaluated by preliminary exams that included antropometric measurements, BP measurements according to guidelines (4) and an interview with a physician for assessing clinical status, medication use, and exercise practice.

Participants who fulfilled all the study criteria underwent three familiarization sessions, one 20-repetition maximum (20RM) test, and 4 experimental sessions. All sessions were conducted in the afternoon (1 to 4 p.m.) in a temperature-controlled laboratory (21 to 23°C). For each session, they were instructed to have a light meal 2 hours before and to avoid drinking coffee, tea, and any other stimulant of central nervous activity during the previous 4 hours. In addition, they should avoid exercising and ingesting alcohol for the previous 24 hours.

During familiarization sessions, participants performed bilateral leg extension exercise in a leg extension machine (Nakagym, Diadema, Brazil). In each session, they executed three sets with a weight that allowed 20RM. If participants performed more or less than 20 repetitions, the weight lifted was increased or decreased, respectively, for the next set. Forty-eight hours after the third familiarization session, a testing session was carried out to determine the weight equivalent to 20RM.

Afterwards, participants underwent four experimental sessions conducted in balanced random order on different days. An interval of at least 48 hours was kept between sessions. In each session, participants performed one of the following RTP: i) HIGH\_W:R\_3x15:44s, ii) LOW\_W:R\_3x15:88s, iii) LOW\_W:R\_9x5:22s, and iv) LOW\_W:R\_45x1:4s. Figure 1 presents a pictorial view of repetitions and intervals in each RTP. All protocols were conducted with an intensity equivalent to 20RM. Concentric and eccentric phases lasted 2s each and were controlled by a
Participants were instructed to breathe normally during exercise execution. All cardiovascular dependent variables were measured before, during, and after each RTP.

**Blood Pressure, Heart Rate and Rate Pressure Product**

Beat by beat BP was continuously measured by finger photoplethysmography (Finometer®; Finapres Medical Systems, Amsterdam, Netherlands) after calibration according to the manufacturer’s recommendations (29). Heart rate (HR) was assessed by electrocardiography (System 1000 Modular Instrumentation; CWE, Inc., Ardmore, OK, USA). Both signals were acquired with a data acquisition system (WinDaq DI-720; Akron, Ohio, USA) with a sample rate of 500 Hz/channel. Rate pressure product (RPP) was calculated as the product between SBP and HR.

For data acquisition, the cuff of the finometer was placed on the left hand of the participants which was supported as shown in Figure 2. All participants were instructed not to move the hand during the recordings. The right hand held a grip handle during the leg extension exercise to improve body stability. This position was kept the same in all RTP performance.

In each experimental session, participants were positioned on the leg extension machine and rested in the sitting position for 7 minutes. Afterwards, beat-to-beat BP and HR measurements were registered for 3 minutes before and throughout the exercise in each RTP. Pre-exercise values were calculated based on the mean values obtained in the resting period. Then, differences (Δ) between each measurement obtained during exercise and the pre-exercise value were calculated, instead of absolute values because photoplethysmographic measurement of BP during resistance exercise was validated by comparison with intraarterial measurements only for responses to exercise (Δ) and not for the absolute values achieved during exercise (17). Afterwards, to evaluate the cardiovascular responses during each RTP, the highest Δ of SBP, DBP, HR, and RPP obtained every 15 repetitions were registered.

**INSERT Figure 2 ABOUT HERE**
Rating of Perceived Exertion and Blood Lactate Concentration

RPE was assessed using the OMNI-resistance exercise scale (33) following every 15 exercise repetitions. Blood samples (25µl) were collected from the earlobe before and at 3 and 5 minutes after the RTP. Blood lactate concentration was measured by electrochemical technique (Lactate Analyzer, Yellow Springs Instruments 2300 Stat Plus, OH, USA) after stabilization in sodium fluoride (5 mM).

Statistical Analysis

Data normality was assessed by the Shapiro-Wilk test and visual inspection. All variables presented normal distribution. Independent T-test was used to compare sample characteristics between men and women. One-way analysis of variance (ANOVA) was used to compare protocol duration among the four RTP (HIGHw/R-3x15:44s; LOWw/R-3x15:88s; LOWw/R-9x5:22s and LOWw/R-45x1:4s). Three-way ANOVA was used to compare ΔSBP, ΔDBP, ΔHR, ΔRPP, RPE, and blood lactate concentration between genders (female or male), RTP (HIGHw/R-3x15:44s, LOWw/R-3x15:88s, LOWw/R-9x5:22s, and LOWw/R-45x1:4s) and moments (15, 30, and 45 reps or pre, 3, and 5 min). When necessary, Newman-Keuls post-hoc test was applied. Significance was set as p<0.05.

RESULTS

Resistance Training Protocol duration

The total duration of RT protocol was significantly shorter in the HIGHw/R-3x15:44s when compared with the others (HIGHw/R-3x15:44s = 250 ± 19 vs. LOWw/R-3x15:88s = 340 ± 15, LOWw/R-9x5:22s = 352 ± 18, and LOWw/R-45x1:4s = 339 ± 35 s, F = 135.6; p<0.001).

Blood Pressure, Heart Rate and Rate Pressure Product

SBP responses observed throughout the four RTP in a participant who represents the mean behavior of the group are shown in Figure 3.

INSERT FIGURE 3 ABOUT HERE
All cardiovascular responses observed during the RTP are shown in Figure 4 (ΔSBP, ΔDBP, ΔHR, and ΔRPP). Data are shown as mean ± SE. For ΔSBP, three-way ANOVA revealed significant main effects for gender, RTP, and moment without any significant interaction. Thus, ΔSBP was greater in men than women (marginal values, $+90\pm 3$ vs. $+63\pm 2$ mmHg, $F = 6.97$, $p = 0.03$), and both genders responded similarly to the RTP and moments. ΔSBP differed among the RTP with HIGH$_{W:R}$-3x15:44s = LOW$_{W:R}$-3x15:88s > LOW$_{W:R}$-45x1:4s > LOW$_{W:R}$-9x5:22s (marginal values, $+87\pm 5$ and $+84\pm 5$ vs. $+61\pm 4$ vs. $+57\pm 4$ mmHg, respectively, $F = 15.3$, $p<0.001$). Finally, ΔSBP increased significantly every 15 repetitions (marginal values, $+62\pm 6$ vs. $+78\pm 6$ vs. $+91\pm 7$ mmHg for 15, 30 and 45 reps, respectively, $F = 101.0$, $p<0.001$).

For ΔDBP, there was no gender effect ($F = 1.14$, $p = 0.31$) and a significant interaction between RTP and moment ($F = 4.71$, $p<0.001$). Thus, in general, ΔDBP differed among the protocols, with HIGH$_{W:R}$-3x15:44s > LOW$_{W:R}$-3x15:88s > LOW$_{W:R}$-45x1:4s > LOW$_{W:R}$-9x5:22s and ΔDBP also increased significantly every 15 repetitions in all the RTP.

For ΔHR, ANOVA showed a significant main effect for RTP and moment without significant main effect for gender ($F = 0.72$, $p = 0.41$). Thus, ΔHR differed among RTP with HIGH$_{W:R}$-3x15:44s = LOW$_{W:R}$-3x15:88s > LOW$_{W:R}$-45x1:4s = LOW$_{W:R}$-9x5:22s (marginal values, $+63\pm 5$ and $+61\pm 4$ vs. $+43\pm 3$ and $+42\pm 4$ bpm, $F = 39.78$, $p<0.001$). In addition, ΔHR increased significantly every 15 repetitions (marginal values, $+44\pm 3$ vs. $+53\pm 4$ vs. $+59\pm 4$ bpm for 15, 30 and 45 reps, respectively, $F = 31.22$, $p<0.001$).

For ΔRPP, there was no gender effect ($F = 0.69$, $p = 0.43$) and a significant interaction between RTP and moment ($F = 3.54$, $p<0.001$). Thus, regardless of gender, in general, ΔRPP differed among the RT protocols with HIGH$_{W:R}$-3x15:44s > LOW$_{W:R}$-3x15:88s > LOW$_{W:R}$-9x5:22s = LOW$_{W:R}$-45x1:4s. In addition, ΔRPP increased significantly every 15 repetitions in all the RTP.

INSERT FIGURE 4 ABOUT HERE
Rating of Perceived Exertion and Blood Lactate Concentration

Three-way ANOVA revealed a significant main effect for RTP and moment for RPE with no significant gender effect ($F = 0.39$, $p=0.55$) (Figure 5). Data were shown as mean ± SE. Thus, RPE differed among protocols with HIGH$_W$:R$_R$-3x15:44s = LOW$_W$:R$_R$-3x15:88s > LOW$_W$:R$_R$-45x1:4s = LOW$_W$:R$_R$-9x5:22s (marginal values, 7.8 ± 0.2 and 7.5 ± 0.2 vs. 6.7 ± 0.1 and 6.2 ± 0.2 a.u., respectively, $F = 24$, $p<0.001$). In addition, RPE increased significantly every 15 repetitions (marginal values, 5.2 ± 0.2 vs. 7.3 ± 0.2 vs. 8.7 ± 0.1 a.u. for 15, 30 and 45 reps, respectively, $F = 150$, $p<0.001$).

Three-way ANOVA also revealed no effect of gender ($F = 2.6$, $p = 0.141$) and a significant interaction between RTP and moment for blood lactate concentration ($F = 12.9$, $p<0.001$) (Figure 5). Data were shown as mean ± SE. Thus, independently of gender, lactate concentration at 3 and 5 min of recovery differed among the protocols with HIGH$_W$:R$_R$-3x15:44s = LOW$_W$:R$_R$-3x15:88s > LOW$_W$:R$_R$-45x1:4s = LOW$_W$:R$_R$-9x5:22s. In addition, lactate concentration was significantly higher at 3 and 5 min of recovery in comparison to pre-exercise in all the RTP.

DISCUSSION

The purpose of this study was to investigate the effects of different RTP with equated and non-equated W:R structure on BP behavior during resistance exercise execution in normotensive men and women. The main findings were that during exercise execution, the protocol HIGH$_W$:R$_R$-3x15:44s produced the highest increases in DBP and RPP, while the protocol LOW$_W$:R$_R$-9x5:22s produced the lowest increases in SBP and DBP. In addition, although men presented higher $\Delta$SBP values than women, $\Delta$DBP, HR, RPP, RPE, and lactate concentration during RTP execution increased similarly between genders.

The four experimental RTP were designed to differ in sets, repetitions, and intervals’ number and duration. The weight lifted was kept constant and equal to 20RM. One of the RTP differed from the others by having a higher W:R (HIGH$_W$:R$_R$-3x15:44s > LOW$_W$:R$_R$-3x15:88s = LOW$_W$:R$_R$-9x5:22s = LOW$_W$:R$_R$-45x1:4s). The hypothesis of this study was that the HIGH$_W$:R$_R$-3x15:44s protocol would cause the highest physiological response. In fact, for variables $\Delta$DBP and $\Delta$RPP, this protocol produced the highest peak responses. However, for $\Delta$SBP and $\Delta$HR, the protocol LOW$_W$:R$_R$-3x15:88s produced responses similar to the HIGH$_W$:R$_R$-3x15:44s. Thus, differently from expected,
reducing RTP W:R by just increasing interval duration did not reduce peak SBP and HR. Similarly, Lamotte et al. (22), studying coronary disease patients, found no difference in SBP increase between two RTP that also differed only in interval duration (3x10:90s vs. 3x10:120s). A previous study (10) has shown, in normotensive individuals, that 45s of interval between sets was enough for recovering SBP and HR to their pre-exercise levels. Thus, increasing the interval duration may not have any further decreasing of peak responses.

The second comparison performed in the present study was among the three RTP equated for W:R. The three protocols were: i) sets and rest intervals longest (LOW\textsubscript{W:R}-3x15:88s); ii) medium sets with short rest intervals (LOW\textsubscript{W:R}-9x5:22s); and iii) sets and rest intervals shortest (LOW\textsubscript{W:R}-45x1:4s). All these protocols summed a W:R of 45reps:176s. In accordance with the study’s hypothesis, although the W:R were similar among the three RTP, the protocol with medium number of sets and short rest intervals (LOW\textsubscript{W:R}-9x5:22s) promoted the lowest ΔSBP and ΔDBP. BP increases during RTP execution is, partially, attributed to central command stimuli that decreases cardiac parasympathetic activity and increases cardiac and peripheral sympathetic activities (24, 28). In addition, when exercise begins, muscle mechanical reflexes are activated and contribute to augment this autonomic adjustment (28). Along the exercise, metabolic products accumulate in the muscle and progressively activates metaboreflex pathway, enhancing peripheral sympathetic activity (24, 28, 34). All these mechanisms result in the progressive increase in BP that is observed along the repetitions during RTP execution (2, 10, 36). The last mechanism may explain why the protocol LOW\textsubscript{W:R}-9x5:22s had resulted in lower BP responses than the LOW\textsubscript{W:R}-3x15:88s. Because the LOW\textsubscript{W:R}-3x15:88s protocol had more repetitions per set, the accumulation of metabolites should have been greater, inducing a greater activation of sympathetic activity, and consequently, greater BP, HR, and RPP responses.

On the other hand, although the protocol LOW\textsubscript{W:R}-45x1:4s had the shortest sets, ΔSBP and ΔDBP were not lower in this protocol than the LOW\textsubscript{W:R}-9x5:22s protocol, which may be explained by the too short rest interval allowed between the sets/repetitions (only 4s). It is known that during the intervals, HR and BP decrease progressively (6). This reduction results from the parasympathetic restoration and sympathetic withdraw that happen after exercise due to the cessation of central command, mechanoreflex, and metaboreflex stimuli (3, 13). Although the first two mechanisms cease as soon as the exercise finishes, imposing a rapid recovery in HR, the metaboreflex stimulation decreases gradually as metabolic products are washed out from the muscle (13), which results in a more gradual decrease in BP. Thus, if the intervals between the sets are too short, metaboreflex cannot be totally
deactivated, which may explain why peak SBP and DBP were higher in the LOW\textsubscript{W:R}-45x1:4s than the LOW\textsubscript{W:R}-9x5:22s protocol, and peak HR and RPP were similar.

Cardiovascular responses observed in the present study were in accordance with the RPE and lactate concentration responses that also presented the highest values in the HIGH\textsubscript{W:R}-3x15:44s and LOW\textsubscript{W:R}-3x15:88s protocols and the lowest values in the LOW\textsubscript{W:R}-9x5:22s and LOW\textsubscript{W:R}-45x1:4s protocols. RPE has been shown to be directly associated with plasma epinephrine, norepinephrine, cortisol, and lactate concentrations as well as with central command and sympathetic activity (24, 25, 28, 33). The accordance between the RPE, blood lactate concentration, and cardiovascular responses strengthens the discussion about the mechanisms exposed before.

Regarding the clinical application of the results, the most important aspect of this study was to show that the protocols designed in accordance with the traditional guidelines (39) and that are usually employed (15, 23) with cardiovascular patients (i.e. HIGH\textsubscript{W:R}-3x15:44s and LOW\textsubscript{W:R}-3x15:88s) showed the highest cardiovascular responses during their execution, raising questions about their applicability in clinical practice. There is some concern in literature that a high peak BP during exercise might trigger the rupture of an aneurism in predisposed participants (19), such as hypertensive individuals (32). The present results add to literature the knowledge that among protocols with the same W:R those with medium sets and short rest intervals, such as the LOW\textsubscript{W:R}-9x5:22s, are better for reducing cardiovascular risk during practice in comparison with protocols with longer sets and longer rest intervals (HIGH\textsubscript{W:R}-3x15:44 or LOW\textsubscript{W:R}-3x15:88s) or with very short sets and short rest intervals (LOW\textsubscript{W:R}-45x1:4s). It is important to note; however, that cardiovascular risk is relevant for patients with cardiovascular disorders such as hypertension, coronary disease, and arrhythmias. The present study was conducted with normotensive participants, and it is possible that hypertensive patients present different responses, since BP increase during RTP differs between normotensive and hypertensive individuals (10). In addition, hypertensive patients usually take medications that may change their responses to RT exercise (16, 36). Thus, future studies should address the comparison between RT protocols of W:R - equated and - nonequated in patients with cardiovascular disorders.

Despite its positive aspects (strong experimental design, intra-subject control, beat-by-beat evaluation of BP, and sample size), the present study presents some limitations. First, it involved normotensive participants although risk might be more relevant in hypertensive participants that should be investigated in the future. Second, this study tested differences in RTP by changing sets, repetitions, and rest intervals without altering weight lifted (20RM). Changes in weight lifted are very important for RTP progression (9, 23), and future studies should be
designed to test its effects on cardiovascular responses during RTP execution. Third, the participants held grip handle with one hand during leg extension execution, which might increase BP response by the isometric contraction of the arm (35). However, as this contraction was equally performed in all the RTP, it might not have influenced the comparison among the protocols. Fourth, some women may have been evaluated at different phases of their menstrual cycle. However, previous studies have reported no influence of menstrual cycle phase on BP responses during RTP (20, 30), this aspect should not have influenced the present results. Finally, results are limited to the comparisons directly done in this study; however, responses might have the same direction if changes in sets, repetitions, and rest intervals follow the same rational as presented here.

The main conclusions of the present study were, in normotensive participants: i) cardiovascular responses during RTP were similar in men and women although ΔSBP levels were greater in men; ii) in general, RTP with higher W:R produced higher cardiovascular responses; however, decreasing W:R by only increasing the rest interval did not decrease peak HR and SBP responses during the RTP; iii) among RTP equated for W:R, those with medium set and short rest intervals promoted lower cardiovascular peaks than those with long sets; and they also promoted lower BP peaks than those with very short rest intervals; and iv) our findings provide information to develop RT protocols that may mitigate pressure peaks without changing important exercise variables (i.e. volume or duration).

PRACTICAL APPLICATIONS

Coaches are concerned with structuring RTP that improve performance and bring safety to the practitioner. In this regard, it is observed that the manipulation of W:R is not reported in most resistance training guidelines. Recently studies have shown that the W:R influences mechanical power output (31), RPE (21), and the current study showed that it also effects cardiovascular stress. Our results confirm that the reduction of W:R (e.g. 45rep:88s vs 45rep:176s) mitigates cardiovascular stress independent of the organization of the RTP (e.g. 3x15 or 9x5 or 45x1). In addition, the new findings of the present study show that among different RTP protocols equated for W:R, those with medium sets and short rest intervals (i.e. LOW\textsubscript{W:R}-9x5:22s) have the greatest possibility of decreasing cardiovascular stress during RTP execution.
REFERENCES


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Figure Legends

FIGURE 1 – Description of the four resistance training protocols employed in the study: HIGH\_W:R-3x15:44s, LOW\_W:R-3x15:88s, LOW\_W:R-9x5:22s, and LOW\_W:R-45x1:4s (sets x reps : rest between sets). In each protocol, repetitions are shown in white and rest periods in gray. Rest intervals coincide after 15 and 30 repetitions.

FIGURE 2 – Left hand position and Finometer cuff placement during acquisition of biological data in leg extension exercise.

FIGURE 3 – Systolic blood pressure (SBP) measured every heart beat in one volunteer during all four resistance training protocols: HIGH\_W:R-3x15:44s, LOW\_W:R-3x15:88s, LOW\_W:R-9x5:22s, and LOW\_W:R-45x1:4s.

FIGURE 4 – Peak changes observed in systolic blood pressure (ΔSBP), diastolic blood pressure (ΔDBP), heart rate (ΔHR), and rate pressure product (ΔRPP) from the 1\textsuperscript{st} to 15\textsuperscript{th} repetitions (15rep), from 16\textsuperscript{th} to 30\textsuperscript{th} repetitions (30rep) and from 31\textsuperscript{st} to 45\textsuperscript{th} repetitions (45rep) during the leg extension exercise performed in the four resistance training protocols: HIGH\_W:R-3x15:44s, LOW\_W:R-3x15:88s, LOW\_W:R-9x5:22s and LOW\_W:R-45x1:4s. As men and women responded similarly to the resistance training protocols, their data were pooled. Values are expressed as mean and standard error. *Different from previous 15 reps (P < 0.05); †Different from LOW\_W:R-3x15x88s (P < 0.05); ‡Different from LOW\_W:R-9x5:22s (P < 0.05); §Different from LOW\_W:R-45x1:4s (P < 0.05).

FIGURE 5 – Rating perceived exertion (RPE) measured every 15 repetitions and blood lactate concentration (Lactate) measured at rest and at 3 and 5min after of each resistance training protocol performed: HIGH\_W:R-3x15:44s, LOW\_W:R-3x15:88s, LOW\_W:R-9x5:22s, and LOW\_W:R-45x1:4s. As men and women responded similarly to the resistance training protocols, their data were pooled. Values are expressed as mean and standard error. *Different from previous 15 reps (P < 0.05); ‡Different from LOW\_W:R-9x5:22s (P < 0.05); §Different from LOW\_W:R-45x1:4s (P < 0.05); & Different from rest.
Table 1. Subjects’ characteristics and strength performance

<table>
<thead>
<tr>
<th>Variables</th>
<th>All (n=20)</th>
<th>Men (n=10)</th>
<th>Women (n=10)</th>
<th>p between genders</th>
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<td>Age (years)</td>
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<td>24.6 ± 5</td>
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</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>23.6 ± 3</td>
<td>24.9 ± 3</td>
<td>22.2 ± 2</td>
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</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>113 ± 9</td>
<td>117 ± 10</td>
<td>109 ± 6</td>
<td>0.04</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>72 ± 5</td>
<td>72 ± 4</td>
<td>72 ± 6</td>
<td>0.35</td>
</tr>
<tr>
<td>Weight of 20RM (kg)</td>
<td>44.7 ± 16</td>
<td>52.0 ± 15.7</td>
<td>39.0 ± 15</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Data = means ± SD. BP = blood pressure, RM = repetitions maximum.
<table>
<thead>
<tr>
<th>Resistance Training Protocol (work to rest)</th>
<th>REPETITIONS AND RESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH W:R - 3x15:44s (Step 3B)</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td></td>
<td>11 12 13 14 15 16 17</td>
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<tr>
<td></td>
<td>18 19 20 21 22 23 24</td>
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<td>25 26 27 28 29 30 31</td>
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<td>32 33 34 35 36 37 38</td>
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<td>39 40 41 42 43 44 45</td>
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<tr>
<td>LOW W:R - 3x15:88s (Step 3B)</td>
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<td>11 12 13 14 15 16 17</td>
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<td>18 19 20 21 22 23 24</td>
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<td>32 33 34 35 36 37 38</td>
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<td></td>
<td>39 40 41 42 43 44 45</td>
</tr>
<tr>
<td>LOW W:R - 9x5:22s (Step 3B)</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
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<td>11 12 13 14 15 16 17</td>
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<td>18 19 20 21 22 23 24</td>
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<td>32 33 34 35 36 37 38</td>
</tr>
<tr>
<td></td>
<td>39 40 41 42 43 44 45</td>
</tr>
<tr>
<td>LOW W:R - 45x1:4s (Step 3B)</td>
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