

# Analysis of hemodynamic responses to resistance exercise performed with different intensities and recovery intervals

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## ABSTRACT

**This aim of the present study was to analyze the hemodynamic responses during resistance exercise performed at different intensities and with different recovery intervals. This study was conducted on twenty-four apparently healthy male individuals ( $25.50 \pm 3.72$  years and  $76.50 \pm 4.50$  kg) experienced in strength training. The volunteers performed a 1RM test to determine the training load for the study. Blood pressure and Rate Pressure Product were measured before and at the end of the exercise training. The only significant difference observed was in SBP during strength training at 70% intensity ( $121.7 \pm 8.68$ ,  $p = 0.039$ ), which was lower than SBP at the remaining intensities of 80% ( $126.3 \pm 7.11$ ) and 90% ( $127.1 \pm 7.51$ ). It was concluded that strength training performed at different intensities and recovery intervals did not significantly alter most variables, changing only the SBP due to the intensity employed.**

**Keywords:** Strength Training (ST); Blood Pressure (BP); Heart Rate (HR); Rate Pressure Product (RPP)

## 1. INTRODUCTION

Strength training (ST) is usually practiced by people seeking benefits such as increased strength, change in body composition and health maintenance [1-3]. Strength training, when related to physical fitness, significantly

reduces the risk of cardiovascular disease, and tends to cause autonomic and hemodynamic adaptations that influence the cardiovascular system to maintain cellular homeostasis in the face of increased metabolic demands [4,5].

Exercise challenges the ability of the coronary arteries to provide enough blood to meet the demand of myocardial oxygen consumption. Heart rate (HR) and systolic blood pressure increase with exercise intensity [6,7]. Systolic blood pressure (SBP) is used to estimate the pressure exerted against the walls of the arteries during ventricular contraction and diastolic blood pressure (DBP) is used to estimate the pressure exerted against the artery walls when blood is not being forcibly ejected through vessel. Blood pressure (BP) alternates between the systolic level and the diastolic level of 120 to 80 mmHg (in rest) [8].

Citing some studies of hypertensive patients, the American College of Sports Medicine Position Stand (ACSM) [9] states that physical activity is important in primary prevention and control of hypertension. The frequency, intensity, time and type of exercise (FITT) are specifically important factors in determining the physiological responses to exercise. Therefore, specific physical activities have been proposed because of their associations with better health and quality of life. However, such activities should meet certain safety criteria when they are prescribed [10].

Among the variables mentioned, yet seldom studied, is the length of periods of rest between sets and different types of exercises, which influences the total stress of training and total load that can be completed [11]. This

variable is considered valuable when developing a program of strength training. Different periods of time between sets and exercises have been used in accordance with the objectives to be achieved.

The doubled-product (or rate pressure product, RPP), defined by the product of HR and SBP, is a variable correlated with myocardial oxygen consumption ( $MVO_2$ ), and is therefore considered the most reliable indicator of the work of the heart during aerobic and anaerobic physical efforts [12]. The RPP is of great importance for the prescription and monitoring of these activities in healthy subjects or in those who have heart disease [12]. Little is known about the responses of HR and RPP during different work interval intensities and recovery interval durations despite the increased frequency of using strength training in hypertensive patients.

The aim of this study was therefore to analyze the response of blood pressure, heart rate and rate pressure product after strength training exercise using different intensities and recovery intervals.

## 2. METODOLOGY

### 2.1. General Protocol

The study consisted of twenty-four male individuals ( $25.50 \pm 3.72$  years,  $76.50 \pm 4.50$  kg) with a minimum experience of 12 months in ST, released for participation in the intervention by a physician. All participants responded negatively to the PAR-Q [13,14]. The volunteers were informed about the study, and all signed an authorization according to resolution no. 196/1996 of the National Health Council, for human experiments, in accordance with the ethical principles contained in the Declaration of Helsinki (1964, revised in 1975, 1983, 1989, 1996 and 2000), the "World Medical Association".

Participants were instructed not to consume caffeine or alcohol for the 24 hours prior to data collection and not to consume food for the 3 hours before the tests: this fact being conferred through interview after the tests. In addition, exclusion criteria were the use of ergogenic aids and medications that could affect cardiovascular responses, as well as SBP and DBP higher, than 139 and 89 mmHg, respectively. These criteria were reconfirmed at each evaluation.

An interview (anamnesis) as well as anthropometric measurements of weight, height and skinfold were conducted [15]. There were two sessions for familiarization and two sessions training load determination, conducted with a minimum of 48 hours between sessions. The training load was established through the 1RM testing of Leg Press. The load determination was performed in two days: one day for testing and the second day for retesting to determine the reliability of the test. **Figure 1** symbolizes the standardization of tests.

### 2.2. Test of 1 Repetition Maximum (1RM)

The 1RM tests were conducted twice after two familiarization sessions according to the protocol proposed by Brown *et al.* [16]. The subjects performed 3 - 5 min of light activities involving the muscle group tested, and after 1 min of light stretching, a warm-up of 8 repetitions at a perceived load of approximately 50% 1RM, followed by 3 repetitions at a perceived load of approximately 70% 1RM. After a five-min recovery period, the 1RM test was conducted by adding when necessary 0.4 to 5 kg to the load until the load could not be successfully lifted. The total number of attempts was 3 - 5 attempts. The maximum load that was raised in one motion was recorded as the 1RM load.

On the fifth day of the trial, after two familiarization sessions and two sessions to determine the maximum load, the SBP, DBP and HR were measured after the subject was seated for 10 minutes in a comfortable position in a quiet environment. After determining the load for the training, the experimental protocol was conducted on three additional days, not consecutive, with a minimum duration of 48 hours between sessions.

On the sixth day of trial, SBP, DBP and HR at rest and after exercise were again measured. Participants, after measuring variables at rest, performed 3 sets with 10 repetitions at 70%, 8 repetitions at 80% and 6 repetitions at 90% of 1RM load in succession [17-20], with sixty second rest intervals. On the seventh and eighth day of assessments, training was repeated, but with intervals between sessions of, 60, 90, and 120 seconds, respectively. If at least one cardiovascular variable in relation to the value observed on the first day, the exercise was not performed and the participant was asked to revisit. Throughout the experiment we adopted a minimum rest of 48 hours between sessions.

Aiming to reduce the margin of error in the test we adopted the following strategies: standardized instructions were provided before testing, the subject was instructed to technical execution of the exercise, including

1 - day Selection of volunteers	2 - day- Interview and anthropometric measurements	3 - day Familiarization of 1RM test	4 - day Retesting of Familiarization of 1RM test
5 - day Familiarization of training load	6 - day Retesting of Familiarization of training load	7 - day SBP, DBP and HR were measured	
8 - day 3 sets with 10 repetitions at 70%, 8 repetitions at 80% and 6 repetitions at 90% - 60' interval	9 - day 3 sets with 10 repetitions at 70%, 8 repetitions at 80% and 6 repetitions at 90% - 90' interval	10 - day 3 sets with 10 repetitions at 70%, 8 repetitions at 80% and 6 repetitions at 90% - 120' interval	

**Figure 1.** Testing days.

multiple familiarization and testing sessions to reduce possible effects of learning.

### 2.3. Measurement of Blood Pressure

BP and HR at rest, during exercise and during recovery were measured with an aneroid sphygmomanometer (Tycos<sup>®</sup>, USA) and stethoscope (Littmann Quality<sup>®</sup>, Germany) and with a heart rate monitor (Polar S725X, Polar Electro OY, Finland), respectively. For the measurement of HR and BP, we took into account the responses of peaks normally occurring during the last repetitions of a series [20]. Thus, data collection occurred at the end of the last repetition of the leg press exercise [20].

The BP measurement was performed in the left arm with the volunteers seated. The proper relationship between the cuff width and arm diameter arm was maintained for all subjects [21] (Kohlmann *et al.*, 1999). Although not the gold standard for blood pressure measurements, our method provides continuous reading of SBP and DBP, and, in the case of the resistance exercise, the most suitable noninvasive method to measure blood pressure [11]. The blood pressure data were recorded in mmHg. Participants were asked to flex their arm at the elbow, with the level of their extended hand at the level of the thorax in order to prevent the data from being contaminated by gravitational action on the extended arm [21]. The subjects were also instructed not to contract or move the arm, hand and fingers where the stethoscope

was attached, as well as to not perform the Valsalva maneuver. The measurement was performed at rest with the subject lying supine so there was no body movement between recordings.

### 2.4. Statistics

Descriptive analysis were performed, using measures of central tendency Data were presented as mean and standard deviation (mean  $\pm$  SD). Normality of the data was checked using the Shapiro Wilk test. Two-factor ANOVA (Intensity and Interval) with Tukey post hoc was used to test for significance, with an alpha level of  $p < 0.05$ . Data analysis was performed using SPSS for Windows 15.0.

## 3. RESULTS

The HR, SBP, DBP and RPP in relation to intensity and rest interval duration are presented in **Tables 1-4**, respectively.

Systolic blood pressure was determined in 24 Participants at the end of a strength training protocol consisting of three sets, with 10 repetitions at 70%, 8 repetitions at 80% and 6 repetitions at 90% of 1RM load with either 60, 90 or 120 second rest intervals between sets.

**Figure 2** shows the response of SBP in 24 participants during strength training at different intensities and interval.

**Table 1.** Heart rate (beats per minutes) at three intensities and three recovery intervals.

Intensity	Interval	N	Mean $\pm$ SD	p
70%		24	117.33 $\pm$ 18.52	0.98
80%		24	116.42 $\pm$ 18.25	
90%		24	117.08 $\pm$ 17.12	
	60"	24	116.21 $\pm$ 18.07	
	90"	24	117.92 $\pm$ 16.68	
	120"	24	116.71 $\pm$ 19.06	

\*  $p < 0.05$ .

**Table 2.** Systolic blood pressure (mmHg) at three intensities and three recovery intervals.

Intensity	Interval	N	Mean $\pm$ SD	$\Delta\%$	p
70%		24	121.7 $\pm$ 8.68*	0.00	0.039
80%		24	126.3 $\pm$ 7.11	3.78	
90%		24	127.1 $\pm$ 7.51	4.43	
	60"	24	127.1 $\pm$ 8.07	4.09	
	90"	24	125.8 $\pm$ 7.17	3.03	
	120"	24	122.1 $\pm$ 8.33	0.00	

\*  $p < 0.05$ .

**Table 3.** Diastolic blood pressure (mmHg) at three intensities and three recovery intervals.

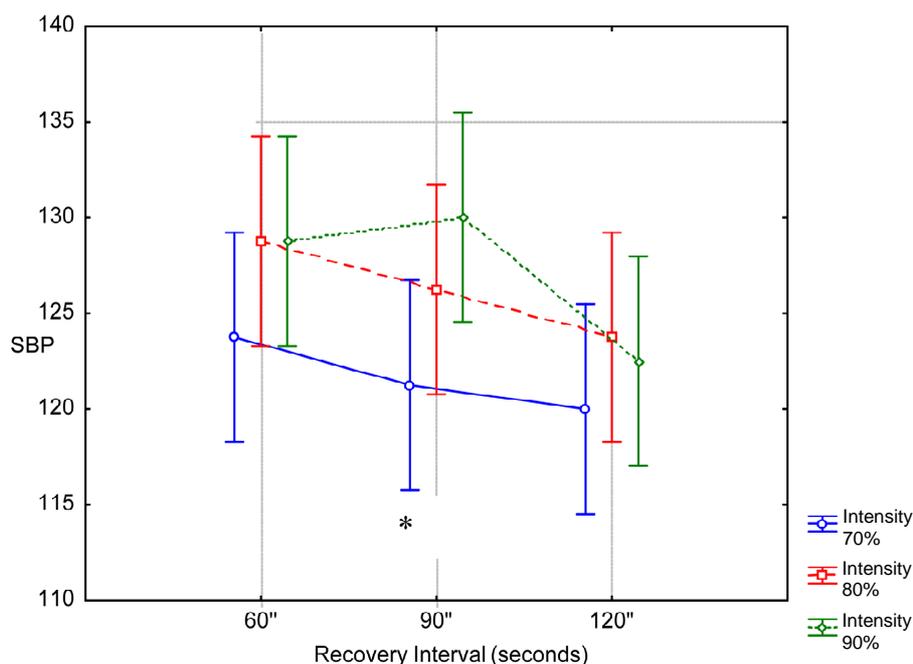
Intensity	Interval	N	Mean ± SD	p
70%		24	85.83 ± 18.86	0.10
80%		24	98.33 ± 11.29	
90%		24	91.67 ± 27.29	
	60"	24	96.25 ± 10.56	
	90"	24	95.42 ± 11.79	
	120"	24	84.17 ± 31.06	

\*p &lt; 0.05.

**Table 4.** Rate pressure product (mmHg × bpm) at three intensities and three recovery intervals.

Intensidade	Intervalo	N	Média ± DP	p
70%		24	14283.75 ± 2520.24	0.70
80%		24	14700.42 ± 2455.22	
90%		24	14877.50 ± 2304.00	
	60"	24	14696.25 ± 2037.33	
	90"	24	14862.08 ± 2419.73	
	120"	24	14303.33 ± 2776.51	

\*p &lt; 0.05.

**Figure 2.** Systolic blood pressure during strength training comprised of different intensities and lengths of rest interval. \*p < 0.05 for systolic blood pressure at 70% compared to 80% and 90%.

No significant differences were observed in the following variables: HR—intensity (p = 0.98), interval (p = 0.95) and intensity/interval (p = 1.00); SBP—interval (p = 0.07), interval/intensity (p = 0.82); DBP, intensity (p =

0.09), interval (p = 0.06), intensity/interval (p = 0.47). RPP, intensity (p = 0.70), interval (p = 0.73) interval/intensity (p = 0.97). However, there was a significant difference in intensity (SBP: p = 0.03).

## 4. DISCUSSION

This aim of the present study was to analyze the hemodynamic responses during resistance exercise performed at different intensities and with different recovery intervals. The only significant difference observed was in SBP during strength training at 70% intensity ( $121.7 \pm 8.68$ ,  $p = 0.039$ ), which was lower than SBP at the remaining intensities of 80% ( $126.3 \pm 7.11$ ) and 90% ( $127.1 \pm 7.51$ ).

Although all individuals were able to complete the required number of sets in each series, shorter recovery time between them may have contributed to a higher physiological stress associated with that work intensity [22]. This could be attributed to two principal mechanisms: one of central and the other of peripheral origin [23]. The central mechanism involves the radiation of impulses from the motor cortex to central cardiovascular control. The peripheral mechanism consists of a reflex pathway that is yet to be fully described [24]. This mechanism is originated in the release of metabolites from muscles that are active (potassium and lactic acid, for example), increasing the osmolarity of interstitial fluid [25]. The release of these substances can activate chemoreceptor, which activates a feedback cardiovascular control center, increasing blood pressure [26,27]. In addition, the increased blood pressure can be influenced by the number of motor units required during exercise. In this case of increased motor unit recruitment, the adjustment would be perceived by mechanoreceptors which, like the chemoreceptor's, inform the cardiovascular control center of the need to modify the cardiovascular responses in relation to the strength and speed of movement [28].

The increase in SBP occurs during the ST due to considerable mechanical resistance to blood flow during muscle contraction. The ST increases blood flow, which results in increased peripheral resistance. This fact causes increased blood pressure, which corresponds to an increase in cardiovascular work, as evidenced by the increased rate pressure product [29-31].

There are few well-controlled studies of the changes in BP and HR associated with varying lengths of recovery interval between sets. The present study found no significant difference between protocols of different intensity ( $p = 0.98$ ), and recovery interval ( $p = 0.95$ ). It is possible that heart rate is associated with the exercise mode due to vascular occlusion being more pronounced in bilateral exercise. With vascular occlusion, venous return is reduced. HR should be increased to avoid compromising cardiac output [32]. However, there were no differences in recorded blood pressure or heart rate for the various series of exercises performed with different intensity or recovery periods.

In the experiment of Miranda *et al.* [10], the authors

compared the heart rate, blood pressure and double product during bench press exercise while sitting or lying on the bench, with 10 repetitions performed at 65% of one repetition maximum (1RM). The authors did not identify significant differences in cardiovascular variables in their comparison of the performance in the seated or supine bench press. These results corroborate our findings in the present study.

Regarding RPP, no significant differences were found for intensity ( $p = 0.70$ ) or recovery interval ( $p = 0.73$ ). The fact that heart rate does not vary may have influenced the RPP results. Although the rate pressure product is not valid for estimating the myocardial oxygen consumption in activities of high intensity and short duration, it can be considered the best indicator of cardiac demand during resistance exercise [33,34]. However, the behavior of RPP depends not only on the intensity but also the type and duration of exercise. Until recently, there was a tendency to consider only aerobic activities safer for subjects with elevated risk of cardiac complications.

Exercises with weights were contraindicated for this population [34]. However, some studies show that the exercise double product with weights is usually lower than that observed in aerobic activities of moderate intensity [10,35,36].

A limitation of this study is the measurement of BP by auscultation because of potential appraiser error. The intra-arterial catheterization, although more accurate in measuring BP, was not feasible for this study due to the invasive process and associated high risk for volunteers. Automated or ambulatory blood pressure monitoring (ABPM) is another reliable method that we could have used, although this system was not available for the current study.

## 5. CONCLUSIONS

Based on the results, we conclude that the resistance training conducted at different intensities and lengths of recovery does not result in measurable differences in diastolic blood pressure or rate pressure product. However, systolic blood pressure was increased with increased intensity.

It is therefore suggested that there be further studies analyzing different methods of strength training to understand the physiological parameters important to determining a safe and effective physical activity prescription.

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## ABBREVIATIONS

ST: Strength Training

HR: Heart Rate

BP: Blood Pressure

SBP: Systolic Blood Pressure

DBP: Diastolic Blood Pressure

RPP: Rate Pressure Product

MVO<sub>2</sub>: Myocardial Oxygen Consumption

1RM: Test of 1 Repetition Maximum

bpm: beats per minutes

ABPM: Ambulatory Blood Pressure Monitoring