**Int J Exerc Sci – MS # 2180**

**We wish to thank the reviewers for their thorough and diligent review. We have addressed all comments below and believe, and hope you agree, we have substantially improved this manuscript.**

**Second Review Round**

**Reviewer #1**

General comment

Thank you for taking the time to revise this manuscript. The readability is much improved. I also feel you enhanced the reference support in a number of important areas. You did a nice job of providing clarification on the methods and the results. This is a high-quality study and the information is now presented in a clear manner, with only a few small grammatical corrections. You have fully addressed my concerns and I think this study will be a great addition to the literature.

**Thank you.**

Specific Comments

**Introduction, 1st paragraph**: Load’s reproducibility in tested mainly through … Change “in” to “is”.

**This has now been amended.**

**Introduction, 3rd paragraph, 2nd to last sentence**: “Authors found that five-sets promoted a substantial cardiac stress to compared …” should read “compared to.

**This has now been amended.**

**Discussion, last paragraph, 1st sentence**: “… cardiovascular healthy and this fact…” Insert the word “individuals” after healthy.

**This has now been amended.**

**Discussion, 2nd sentence**: “Even increasing sympathetic activity during 10 RM test does not maintenance an exacerbated…” Change maintenance to “maintain”.

**This has now been amended.**

**First Review Round**

**Reviewer #1**

General comment

Thank you for this contribution to the literature. I think this is a well done study with regard to the protocol and the attempt to make procedures consistent. There were a number of grammatical erros or word choices that made the article a bit challenging to understand at times. I have provided comments, suggestions, and feedback to help address those areas. Looking past the grammatical issues, I think this article was well designed, executed and analyzed, but the article will need some work to make it more reader friendly.

**Thank you for the kind words. English grammar has been thoroughly checked and corrected throughout the paper as suggested by native English speakers.**

Specific Comments

For specific comments I tried to provide the page and paragraph for reference. I used the page numbers at the bottom of the pages. In many cases, I copied the text exactly from the manuscript and the provided my feedback or suggested changes.

**Thank you.**

**Abstract:** In the abstract: The second to last sentence states, “Thus, it seems to be safe for cardiovascular healthy.” Doesn’t read well. Perhaps you meant “cardiovascular health” or “cardiovascularly healthy individuals.”. Sentence needs to be fixed. No page number on the first page of the article.

**This has now been amended.**

**Page 1, paragraph 1:** Sentence that begins with “Therefore, repetition maximum (RM)…, besides for loads control in experimental protocols”. The word load should be singular no plural. I would also change “besides” to “in addition to” which has a more professional tone.

**We have now clarified this, the section now reads as follows: ‘Therefore, repetition maximum (RM) tests have been used for measuring and evaluating the muscle force, in addition to load control in experimental protocols (6), like a maximum repetition range (28).’**

**Page 1, Paragraph 2**: “Heart rate variability (HRV) is an important cardiovascular regulator which reflects the influence of the autonomic nervous system **on heart** (22)”. Insert the word “the” before heart.

**This has now been amended.**

**Page 1, Paragraph 3**: “For example, Figueiredo et al. (11) compared the **acutely** effects of sets volume of RT on HRV in eleven experienced males.” Should be “acute”. Also term “sets volume” is confusing. Volume is reps times sets. Perhaps something like “…compared the acute effects of volume of RT on HRV in eleven experienced males. Volume was manipulated by adjusting the number of sets.”

**We have now clarified this, the section now reads as follows: ‘For example, Figueiredo et al. (11) compared the acute effects of sets RT volume on HRV in eleven experienced males.’**

**Page 1, Paragraph 3**: “Authors’ found that five-sets promoted a substantial cardiac stress in compared one- and three-sets” Remove “in” before compared and add “to” after compared. It should read “…cardiac stress compared to…”

**This has now been amended.**

**Page 1, Paragraph 3:** “On the other hands, Figueiredo et al. (12) found that moderate load intensity (70% of 1RM) provide a better stimulus when compared with 60 or 80 **percentage** of 1RM loads.” Should be “percent”

**This has now been amended.**

**Page 1, Paragraph 4**: “To our best acknowledge…” Should read “To the best of our knowledge…”

**This has now been amended.**

**Page 1 paragraph 4**: “It was hypothesized that 10RM load test would promote a cardiovascular stress and recovered before 60-minutes.” Should be “…recover before 60-minutes.” Because you want the verbs to match…promote is in the present tense and therefore recover should be as well.

**This has now been amended.**

**Page 1, participants**: Women is the plural form of woman, therefore no “ ‘s” is needed.

**This has now been amended.**

**Page 2, protocol**: Is baseline, pre-RT or is it immediately upon completion of the RT? Should make that clearer.

**We have now clarified this, the section now reads as follows: ‘HRV data were recorded at baseline and four moments postexercise (15-minutes [Post-15], 30-minutes [Post-30], 45-minutes [Post-45], and 60-minutes [Post-60].’**

**Page 2, protocol**: For each post exercise time period you have provided coding except what should be P60. Please make consistent.

**We have now clarified this, the section now reads as follows: ‘HRV data were recorded at baseline and four moments postexercise (15-minutes [Post-15], 30-minutes [Post-30], 45-minutes [Post-45], and 60-minutes [Post-60].’**

**Page 2, protolcol:** “Only the first 10RM test day were used for analysis”. Should be “was” not were. Your subject is singular.

**This has now been amended.**

**Page 3, top of the page, b):** “subjects received feedback as to their technique and were corrected appropriate,” should read “as appropriate” or “as necessary”.

**This has now been amended.**

**Page 3, paragraph 1**: “and data was simultaneously transmitted to and stores in a watch.” Verbs need to be consistent, therefore it should read “stored” instead of stores.

**This has now been amended.**

**Page 3, paragraph 1:** This sentence reads awkwardly. Does the word greater also qualify the sampling rate? “Period with greater signal stability and sampling rate of 5- minutes as recommended by the Task Force (29) was selected.” If I am understanding this correctly, you may want to say something like “Using a sampling rate of 5-minutes as recommended by the Task Force, periods were selected based on having greater signal stability.” Not sure if that captures the intent of the statement, but it is confusing

as you have it.

**We have now clarified this, the section now reads as follows: ‘Using a sampling rate of 5-minutes as recommended by the Task Force (29), periods were selected based on having greater signal stability.’**

**Page 3, statistical analysis**: Mauchaly’s should be Mauchly’s

**This has now been amended.**

**Page 3, statistical analysis:** “Additionally, effect sizes (ES) estimates were calculated…” Size should be singular, thus remove the “s”

**This has now been amended.**

**Page 4, 1st paragraph under table 1:** This doesn’t read well. Either change it to “when comparing…” or when P0 is compared with P15), for example. “…when compared P0 with P15 (p = 0.010), MRRms (F = 4.556; p = 0.005) when compared P0 with P15 (p = 0.026), MHR (F = 4.270; p = 0.006) when compared P0 with P15 (p = 0.006) and PNN50% (F = 4.663; p = 0.005) when compared P0 with P15 (p = 0.006).”

**We have now clarified this, the section now reads as follows: ‘For frequency domain (Table 1), no significant differences were found at any time point for LF (F = 0.981; *p* = 0.431), HF (F = 1.002; *p* = 0.420), and LF/HF (F = 0.652; *p* = 0.629).**

**For time domain (Table 2), no significant differences were found at any time point for SDNNms (F = 1.540; *p* = 0.212) and STD\_HR (F = 0.171; *p* = 0.952). There was a single significant difference in Post-15 for RMSSDms (F = 4.470; *p* = 0.010), MRRms (F = 4.556; *p* = 0.026), MHR (F = 4.270; *p* = 0.006), and PNN50% (F = 4.663; *p* = 0.006) when compared to baseline.’**

**Page 5, under table 2:** “Statistical difference in compared to P0.” Could read “statistical differences when compared to P0.” Or just remove “in”.

**We have now clarified this, see answer above.**

**Page 5, Discussion:** So, was your hypothesis that HR would recover in 60 minutes or that it would recover in 60 minutes or less? Your statement is worded in a way that made it sound like you thought it would take 60 minutes. You say that your data supports the hypothesis, but it recovered in 15 minutes. Please clarify your hypothesis.

**We have now clarified this, the introduction and discussion section now read as follows: ‘It was hypothesized that 10 RM load test would promote a cardiovascular stress and recover in 60-minutes or less.’**

**Page 5, Discussion 2nd paragraph:** This is a very awkward sentence. It needs to be reworked to be clearer. “Although 1RM test is conventionally recommended for testing muscle force, it has relevant practical application limitations for your loads percentage makes possible performed a large number of repetitions and discrepancy when compared differents muscle group sizes and training level (15).” The word “differents” should be replaced with “to different”

**We have now clarified this, the section now reads as follows: ‘Although 1 RM test is conventionally recommended for testing muscle force, it has relevant practical application limitations for your loads percentage. For example, it is possible performed a large number of repetitions and discrepancy when compared to different muscle group sizes and training level (15).’**

**Page 5, Discussion 2nd paragraph:** “results should not be neglected, since the drop could happen at moment where the blood pressure was higher (1).” The comma should be removed after “neglected”. It should read “at a moment”. And “a” to that part of the sentence.

**This has now been amended.**

**Page 5, Discussion, 2nd paragraph:** “Likewise, sympathetic activity was elevated and subsequent HRV reduction, which consequently reduction the cardiac vagal tone.” This sentence is confusing. I think you are looking to use the word “reduced” instead of reduction. So, maybe changing the wording to “HRV was reduced, which consequently reduced the cardiac vagal tone.”

**This has now been amended.**

**Page 5, discussion, 2nd paragraph:** “A highest sympathetic activity 15-minutes postexercise can be explained by some mechanism.” The highest sympathetic activity occurred at 15 minutes post exercise which can be explained by some mechanism**s**. You give a few explanations so this should be plural. Also there were a few words missing to make this sentence read smoothly.

**We have now clarified this, the section now reads as follows: ‘The highest sympathetic activity occurred at 15-minutes postexercise which can be explained by some mechanisms.’**

**Page 5, discussion, 2nd paragraph:** “For example, high intensity RT-exercise stimulates fasttwitch muscle fiber that has great non-aerobic glycolytic capacity and produces high amounts of lactate.” It should read “…muscle fibers that have…” because it would stimulate more than one fiber and therefore it should use the verb form of have, not has.

**This has now been amended.**

**Page 5, discussion, 2nd paragraph, last sentence:** “released” instead of release.

**We have amended the wording as suggested.**

**Page 5, discussion, 3rd paragraph:** previous attempts. This should be plural.

**We have amended the wording as suggested.**

**Page 5, last line:** “Thereby, the flattening of postexercise sympathetic (response?) may not be….” Seems like there is a word missing after sympathetic.

**We have amended the wording as suggested.**

**Page 6, first paragraph:** “The volume performed by subjects was no standardized because it was a test.” No should be “not”.

**We have amended the wording as suggested.**

**Page 6, first paragraph:** “That is, a number of subjects may found the 10RM load in less trials (sets) when compared the others.” -- should be “may have found”

**We have amended the wording as suggested.**

**Page 6, first paragraph:** “Rezk et al. (23) observed the behavior of HRV after RT and regardless of intensity found significantly increases in sympathetic activity postexercise.” – should be “significant increases…”

**We have amended the wording as suggested.**

**Page 6, first paragraph:** “Thus, the results denote a greater relevance for training volumes in compared to RT-intensities.” -- “when compared” instead of “in compared”

**We have amended the wording as suggested.**

**Page 6, second paragraph:** “Although male produces more muscle force”—should be “males produce”

**We have amended the wording as suggested.**

**Page 6, second paragraph**: “Anyway, the pace control of movement should be controlled by the intensity load, since more intense loads do not allow slowly movements.” – should be “intensity of the load” and “for slow movements”

**We have amended the wording as suggested.**

**Page 6, 3rd paragraph:** “In conclusion, the present results demonstrate that load tests, although works with maximum intensities, are safe for cardiovascular healthy, and there did not maintenance an exacerbated postexercise sympathetic activity.” This sentence needs to be clearer from “although” on. One example, “…although they work with maximum intensities, are safe for cardiovascularly healthy individuals”. The next part of that sentence I am not exactly sure what you are trying to convey

**We have now clarified this, the section now reads as follows: ‘In conclusion, although participants work with maximum intensities, 10 RM test are safe for cardiovascular healthy and this fact is confirmed by the results described in the present study. Even increasing sympathetic activity during 10 RM test does not maintenance an exacerbated postexercise sympathetic activity. Literature needs further research about this topic. As a practical application, these results can encourage exercise practitioners to do maximum load tests to RT load prescription.’**

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**Reviewer #6**

Introduction

While resistance training (RT) does elicit physiological changes such as hypertrophy to the skeletal muscle and is beneficial, the authors state hat RT is “important component” of exercise programming and has been used to treat and prevent cardiovascular disorders. Where is the evidence of this? RT is not a cardiovascular exercise, more background on how you came to using resistance training on the lower limbs in needed.

**We have now added references to support this statement, the section now reads as follows: ‘RT may be practiced in different modalities and intensity, which produce different cardiovascular stress. RT is an important component of exercise programming and has been recommended as n nonpharmacological behavioral intervention to prevent and treat cardiovascular disorders (1,7).’**

There is more physiology involved as to why the previous authors found what they did, speak to that more to build upon what lead you to your current inquiry.

**We have now added this sentence: ‘Finally, it seems that exhaustive efforts cause imbalance in the redox balance, produces superoxide and this interacting with nitric oxide form peroxynitrite (37). Peroxynitrite causes a deleterious effect on the vascular endothelium and reduces the availability of nitric oxide, which consequently does not exert a vasodilatory effect (37). Although the present study did not measure oxidative stress markers, such a hypothesis seems to consistently confirm our findings.’**

Methods

The manuscript does not appear to address review board study approval or voluntary

consent of the participants in Study. Please add in.

**The study was conducted respecting all ethical issues. However, in the authors instructions do not mention the responsibility to cite the review board number. Therefore, we believe that this issue should not be taken into account during the evaluation of the present paper.**

**Direct quote from the authors instruction: ‘…Experiments involving the use of human participants must follow procedures in accordance with the ethical standards of the Helsinki Declaration…’**

**Direct quote from the present paper: ‘All procedures were in accordance with Declaration of Helsinki’.**

How did you determine if there was any heart rate variability in this healthy population?

You have been better served in using a population that had a history of a myocardial

infarction to test your hypothesis.

**The 1 RM loading test is usually used for RT trained subjects and free from medical conditions (includes cardiovascular problems here). The purpose of the present study was to verify the safety of the proposed test, thus making comparisons of post-test moments with the baseline. The familiarization sessions as well as the PAR-Q were used to select the subjects eligible to participate in the present study.**

Did the women do a test and re-test on the two separate visits?

**Yes. Direct quote from the present paper: ‘All participants were required to participate in two separate sessions. On the first two visits, a 10 RM load testing and retesting was conducted for the smith back squat (BS), leg press incline (LP), leg extension (LE), and leg flexion (LF), with forty-eight-hours recovery between the visits’.**

If you are testing the HR variability of lower limb exercise for up to 60 minutes post

exercise, why are there other exercises ever 15 minutes

**HRV were collected during baseline and postexercise (10 RM test). The postexercise were cut in 15-minutes range for analyzes. So, we compared 4 post exercise moments (Post-15, Post-30, Post-45, and Post-60) with baseline values.**

**Direct quote from the present paper: ‘HRV data were recorded at baseline and four moments postexercise (15-minutes [Post-15], 30-minutes [Post-30], 45-minutes [Post-45], and 60-minutes [Post-60]).’**

Were 10 repetitions enough to elicit a change in the heart rate after the 15 minutes?

Might have been good to track in per minute to assess the time to return to baseline.

**Yes. Our results (MRRms – means heart rate) indicate changes in this component. Please, see our Table 2 in results section.**

Not sure if your measurements were appropriate to capture what you were

investigating.

**The purpose of the present study was to analyze the acute HRV behavior after 10 RM load test for back squat, leg press, leg extension, and leg flexion in normotensive subjects. The literature indicates good reproducibility of the 10 RM and HRV to test training load and autonomic responses. Thus, we believe that the instruments used are in accordance with the proposal paper.**

How soon after the cessation of exercise was HR taken?

**60-minutes. Direct quote from the present paper: ‘HRV data were recorded at baseline and four moments postexercise (15-minutes [Post-15], 30-minutes [Post-30], 45-minutes [Post-45], and 60-minutes [Post-60]).’**

How soon before the exercise session was the HR taken?

**15-minutes. Direct quote from the present paper: ‘A heart rate monitor (Polar RS800cx; Kempele, Finland), beat-by-beat, was used for 15-minutes before and 60-minutes after experimental session’.**

**‘Using a sampling rate of 5-minutes as recommended by the Task Force (29), periods were selected based on having greater signal stability.’**

Results

Your results need to be explained. The charts are not so clear as to what you found in

your study.

**We have now clarified this, the section now reads as follows: ‘The reliability of 10 RM testing for BS, LP, LE, and LF were 0.97, 0.94, 0.98, and 0.95, respectively. There were no differences between testing days (*p* > 0.05).’**

**‘For frequency domain (Table 1), no significant differences were found at any time point for LF (F = 0.981; *p* = 0.431), HF (F = 1.002; *p* = 0.420), and LF/HF (F = 0.652; *p* = 0.629).’**

**‘For time domain (Table 2), no significant differences were found at any time point for SDNNms (F = 1.540; *p* = 0.212) and STD\_HR (F = 0.171; *p* = 0.952). There was a single significant difference in Post-15 for RMSSDms (F = 4.470; *p* = 0.010), MRRms (F = 4.556; *p* = 0.026), MHR (F = 4.270; *p* = 0.006), and PNN50% (F = 4.663; *p* = 0.006) when compared to baseline.’**

Discussion

The paper seemed to be attempting to make the case that the 10RM should be used in

clinical populations, but this cannot be drawn from this data as your population was

healthy.

**The discussion of the present study was intended to confront the results found in the present study with those previously found in the literature and to sustain the results and the hypothesis raised by the authors. Some modifications are made in the discussion for better reading and interpretation fluency.**

It is unclear if heart rate variability is at play here due to the exercise, as there is no

change over time.

**Although the present study did not have a control group, the fact to be investigated was the autonomic safety in the moments after the test. Regardless of how HRV would behave in other situations at later times to the test, there was even brief an increase in sympathetic activity.**

Tables and Figures

Figure 1. Please indicate when you recorded heart rate.

**Figure was modified as suggested.**

Tables are a bit hard to read, consider cleaning up or using only ones that cannot be described in the results section.

**Tables were modified as suggested.**

Comprehensive

Items need to be revised for English syntax and readability.

**English grammar has been thoroughly checked and corrected throughout the paper as suggested by native English speakers.**

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**Reviewer #9**

Women were recreationally trained. Effect size table reference values were used for untrained individuals. (Please make the corrections in the results table as well as in the methodology).

Correct the experience time (17.2 ± 6.2 years???) would be months.

**We have amended the wording as suggested and the section now reads as follows: ‘Eight recreationally RT-trained women (age: 21.8 ± 2.2 yrs; height: 167.6 ± 6.3 cm; weight: 61.6 ± 10.1 kg) without any musculoskeletal injury or pain were recruited for this based on a *priori* sample size calculation (5).’**

**No change in effect size is adequate. Independent of the reference, the effect size is a mathematical treatment (statistical analyze), whose function is to calculate the magnitude of the effect, regardless of training level. The effect size takes into account the mean and standard deviation of the results, which is not influenced by the training level.**

Make corrections to the effect size using reference values ​​for recreationally trained individuals.

**Answered above**

In this section of the text, or rather in this paragraph that wrote a little about the physiological mechanisms that cause the increase of sympathetic activity, describe and explain a little more. Make a new paragraph on the physiological mechanisms, the article he cited is a very thorough review of the subject, could extract the information there. When you talk about afferent fibers, it does not explain what fibers are. which is the type of fiber, there are 5 types of afferent fibers, with distinct functions, which you are referring to, are type IV. For the afferent fibers stimulated by the metabolites, mainly by the lactate and hydrogen, which diminish the muscular blood Ph, stimulating the fibers and that consequently they will carry synapses until the sympathetic nervous system, stimulating it. Anyway, I would like you to explain more about the physiological mechanisms.

**We have now amended this, the section now reads as follows: ‘The control of cardiac function is mediated from an intrinsic complex and well-structured system involving the participation of afferent and efferent pathways for driving stimuli to the central nervous system and peripheral responses. Structures such as vertebral column, vagus nerve, dorsal root ganglia, brainstem, hypothalamus, thalamus, amygdala and cerebral cortex participate in this process. Afferent nerve fibers (type 3 – myelinated, type 4 - amielinized) are present during exercise, which are sensitive to mechanical and metabolic stimuli, respectively. These fibers have a relevant participation in the control of variables such as blood pressure and heart rate during exercise; that’s is, depending on the exercise intensity may influence metabolic markers such as lactacidemia and ph and consequently, the feedback process that will impact on cardiovascular modulation effects such as HRV.’**

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# *Original Research*

**Behavior of Heart Rate Variability After 10 Repetitions Maximum Load Test for Lower Limbs**

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ABSTRACT

***International Journal of Exercise Science V(i): X-Y, YEAR.*** The purpose of this study was to analyze the acute heart rate variability behavior after 10 repetitions maximum load test for back squat, leg press, leg extension, and leg flexion in normotensive subjects. Eight recreationally trained women (age: 21.8 ± 2.2 yrs; height: 167.6 ± 6.3 cm; weight: 61.6 ± 10.1 kg) performed two 10 repetitions maximum testing days with 48-hours rest between each one. Heart rate variability was measured in baseline and postexercise (15-, 30-, 45-, and 60-minutes) for time and frequency domain. A significant difference was identified in RMSSDms (*p* = 0.010; effect size = -1.3), MRRms (*p* = 0.026; effect size = -1.3), MHR (*p* = 0.006; effect size = 1.4), and PNN50% (*p* = 0.006; effect size = -1.6) when compared 15 minutes postexercise with baseline. For all others comparison and index were no differences (*p* > 0.05). The present study demonstrates that load test, although works with maximum intensities, did not generate an exacerbated postexercise sympathetic activity. Thus, it seems to be safe for cardiovascular healthy individuals. As a practical application, these results can encourage exercise practitioners to do a maximum load test to resistance training loads prescription.

KEY WORDS: Resistance training, performance, autonomic response, sympathetic activity, parasympathetic activity.

## INTRODUCTION

Resistance training (RT) is commonly used to improve strength or force (17,33,34), hypertrophy (34), and power (2) gains. Muscle force involves overcoming inertia through muscular contraction by combining concentric and eccentric actions (16). Therefore, repetition maximum (RM) tests have been used for measuring and evaluating the muscle force, in addition to load control in experimental protocols (6), like a maximum repetition range (36). Usually, 10RM load test consist of two testing days (test and retest) with three maximum attempts in each day. Load’s reproducibility is tested mainly through the intraclass correlation coefficient (ICC), which defines acceptable difference between testing days lower than 5% (36).

RT may be practiced in different modalities and intensity, which produce different cardiovascular stress. RT is an important component of exercise programming and has been recommended as a nonpharmacological behavioral intervention to prevent and treat cardiovascular disorders (1,7,20). Heart rate variability (HRV) is an important cardiovascular regulator which reflects the influence of the autonomic nervous system on the heart (30). Higher HRV indicates good cardiovascular health and adaptation of the central nervous system (10). But, decreases in HRV after myocardial infarction is a risk factor for mortality (4,10,38). Studies (13-15,31) showed increases in sympathetic nervous system activity after RT-session for exercise order and intensity.

For example, Figueiredo et al. (14) compared the acute effects of sets RT volume on HRV in eleven experienced males. Subjects performed a single-set, three-sets, and five-sets, in randomized order, of 8-10 repetition submaximal (70% of 1 RM) with 2-minutes rest interval between exercises for bench press, lat pull down, shoulder press, biceps curl, triceps extension, leg press, leg extension, and leg curl. Authors’ found that five-sets promoted a substantial cardiac stress compared to one- and three-sets. On the other hands, Figueiredo et al. (15) found that moderate load intensity (70% of 1 RM) provide a better stimulus when compared with 60 or 80 percent of 1 RM loads.

To the best of our knowledge no previous research has analyzed the effects of 10 RM load test on acutely HRV response. Thus, the purpose of the present study was to analyze the acute HRV behavior after 10 RM load test for back squat, leg press, leg extension, and leg flexion in normotensive subjects. It was hypothesized that 10 RM load test would promote a cardiovascular stress and recover in 60-minutes or less.

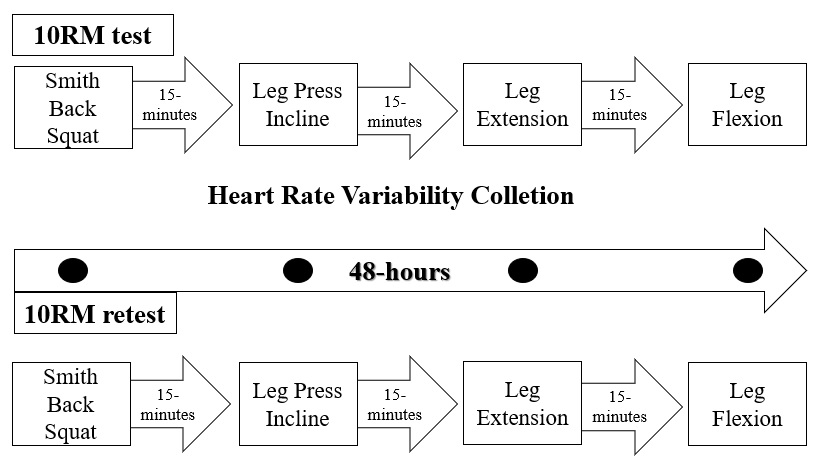
## Methods

*Participants*

Eight recreationally RT-trained women (age: 21.8 ± 2.2 yrs; height: 167.6 ± 6.3 cm; weight: 61.6 ± 10.1 kg) without any musculoskeletal injury or pain were recruited for this based on a *priori* sample size calculation (5). Woman were recruited both out of convenience and to help narrow the gender disparity in sports and exercise medicine research (8). An *a* *priori* sample size calculation (effect size = 23.4; *1-b* = 0.95; *a* = 0.05) using G\*Power (12) found that 6 participants would be sufficient to investigate the question posed. Anthropometric data included body mass (Techline BAL – 150 digital scale, São Paulo, Brazil) and height (stadiometer ES 2030 Sanny, São Paulo, Brazil). Participants were required to have no less than twelve months’ RT experience (17.2 ± 6.2 months), average of 50-60 minutes per session, 3-4 sessions per week, using loads with 6-12 repetition maximum, and rest intervals between 1 and 3 minutes among sets and exercises (2). All participants were asked to not ingest caffeine or alcohol during the 24-hours period, and instructed to refrain from participating in any lower body exercise or strenuous activity throughout the present study. Women performed the procedures in the luteal phase of the menstrual cycle (25). A Physical Activity Readiness Questionnaire (PAR-Q) was used as a screening mechanism (35). All procedures were in accordance with Declaration of Helsinki.

*Protocol*

All participants were required to participate in two separate sessions. On the first two visits, a 10 RM load testing and retesting was conducted for the smith back squat (BS), leg press incline (LP), leg extension (LE), and leg flexion (LF), with forty-eight-hours recovery between the visits. HRV data were recorded at baseline and four moments postexercise (15-minutes [Post-15], 30-minutes [Post-30], 45-minutes [Post-45], and 60-minutes [Post-60]). Only the first 10 RM test day was used for analysis.



**Figure 1**. Flowchart representing the experimental study design.

Participants’ 10 RM was determined in a method describe by Simão et al. (36). Briefly, participants initially performed a standardized warm up consisting of fifteen repetitions of BS, LP, LE and LF with a self-suggested load, approximately 50% of normal training load. Following the warm up, 10 RM testing was performed for all exercises in same day in randomized order with fifteen-minutes rest interval between exercises. Execution of the exercises was standardized insofar as no pauses were allowed between concentric and eccentric portions of the lift. A maximum of three trials were allowed per testing session, separated by three minutes of passive rest. Testing was then repeated on another day at least 48 hours later (retest). In an effort to minimize potential error variance, the following strategies were adopted (36): a) all subjects received standardized instructions about the exercise technique and data collection, b) subjects received feedback as to their technique and were corrected as appropriate, and c) subjects were always verbally encouraged. The exercise apparatus used for 10 RM testing and during the experimental sessions was the same (Turbine Line for BS and LP and Inside Line for LE and LF, Buick, Rio de Janeiro, Brazil). The greater load between the two testing days deemed the 10RM load. Loads reproducibility between the two testing days was tested by ICC.

A heart rate monitor (Polar RS800cx; Kempele, Finland), beat-by-beat, was used for 15-minutes before and 60-minutes after experimental session. HRV data were collected with participants’ lying in supine position in a quiet room with temperature maintained between 20 and 22.8 ºC. The heart rate monitor had a sampling frequency of 1.000 Hz. It was fixed using an elastic belt to the lower third of the sternum (xiphoid process) and data was simultaneously transmitted to and stored in a watch. Data were recorded and subsequently downloaded to a computer (Intel Celeron, 1.50 GHz) for analysis (Kubios®, V.2.0 Released November 2008, Kuopio, Finland) by a serial port interface of an infrared sensor. Data were digitized and analyzed for time and frequency domain. Using a sampling rate of 5-minutes as recommended by the Task Force (1996), periods were selected based on having greater signal stability. The spectral analysis in the frequency domain was performed by Fourier transform algorithm. HRV parameters were analyzed according to the components of low frequency in normalized units (LFnu), high frequency in normalized units (HFnu), LF/HF ratio, standardized deviation of differences between adjacent normal R-R intervals (RMSSDms), standard deviation of all normal R-R intervals (SDNNms) and heart rate (STD\_HR), means of all R-R intervals (MRRms) and heart rate (MHR) and percentage of normal R-R intervals (PNN50%). This value provides information about the sympathetic and parasympathetic nervous system activity (4,30).

*Statistical Analysis*

Initially, the ICC was calculated between testing days by the equation: ICC = [MSb – MSw] / [MSb + {k -1}. MSw]), where MSb = mean-square between, MSw = mean-square within and k = average group size. Data are presented as means ± standard deviations. Normality and sphericity were tested using a Shapiro-Wilk test and homoscedasticity was confirmed by a Mauchly’ test. A one-way ANOVA with repeated measures was used to test for an interaction. Significant differences were identified using a Tukey HSD post-hoc test. Student’s paired *T*-test were used to determine any differences between testing days. Additionally, effect size (ES) estimates were calculated using the standardized mean difference to determine the magnitude of the treatment effects. The ES represent the standardized within-group change for each measurement time point compared with resting values (ES = [Mean Post – Mean Pre] / SD of the resting or pre-value). The magnitude of the ES was interpreted using the scale proposed by Rhea (32) for recreationally trained subjects, where < 0.5, 0.50-1.25, 1.25-1.9, and > 2.0 represented trivial, small, moderate, and large effects, respectively. The alpha was set at *p* < 0.05, and all statistical analysis was performed using SPSS version 21 (SPSS Inc, Chicago, IL, USA).

**RESULTS**

The reliability of 10 RM testing for BS, LP, LE, and LF were 0.97, 0.94, 0.98, and 0.95, respectively. There were no differences between testing days (*p* > 0.05).

For frequency domain (Table 1), no significant differences were found at any time point for LF (F = 0.981; *p* = 0.431), HF (F = 1.002; *p* = 0.420), and LF/HF (F = 0.652; *p* = 0.629).

**Table 1.** Comparison and ES for frequency domain HRV at baseline and postexercise.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Baseline | Post-15 | Post-30 | Post-45 | Post-60 |
| LF (nu) | 43.51 ± 8.63 | 33.48 ± 10.38 | 33.51 ± 10.92 | 38.11 ± 14.19 | 36.69 ± 13.32 |
| ES |  | -1.16 (Small) | -1.15 (Small) | -0.62 (Small) | -0,79 (Small) |
| HF (nu) | 56.38 ± 8.60 | 66.39 ± 10.45 | 66.28 ± 11.04 | 61.81 ± 14.20 | 63.20 ± 13.38 |
| ES |  | 1.16 (Small) | 1.15 (Small) | 0.63 (Small) | 0.79 (Small) |
| LF/HF (ratio) | 1.39 ± 0.55 | 2.44 ± 1.85 | 2.48 ± 1.85 | 1.10 ± 1.53 | 2.16 ± 1.53 |
| ES |  | 1.90 (Moderate) | 1.98 (Moderate) | -0,84 (Small) | 1.40 (Moderate) |

LF = low frequency; HF = high frequency; ES = effect size; Baseline; Post-15 = 15-minutes postexercise; Post-30 = 30-minutes postexercise; Post-45 = 45-minutes postexercise; Post-60 = 60-minutes postexercise.

For time domain (Table 2), no significant differences were found at any time point for SDNNms (F = 1.540; *p* = 0.212) and STD\_HR (F = 0.171; *p* = 0.952). There was a single significant difference in Post-15 for RMSSDms (F = 4.470; *p* = 0.010), MRRms (F = 4.556; *p* = 0.026), MHR (F = 4.270; *p* = 0.006), and PNN50% (F = 4.663; *p* = 0.006) when compared to baseline.

**Table 2.** Comparison and ES for time domain HRV at baseline and postexercise.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Baseline | Post-15 | Post-30 | Post-45 | Post-60 |
| RMSSD (nu) | 49.54 ± 15.42 | 28.90 ± 7.94\* | 33.73 ± 9.71 | 39.45 ± 13.17 | 47.14 ± 10.57 |
| ES |  | -1.33 (Moderate) | -1.02 (Small) | -0.65 (Small) | -0.15 (Trivial) |
| SDNN (nu) | 65.06 ± 25.29 | 48.29 ± 11.00 | 59.35 ± 20.62 | 73.16 ± 22.74 | 73.16 ± 22.74 |
| ES |  | -0,66 (Small) | -0.22 (Trivial) | -0.32 (Trivial) | 0.32 (Trivial) |
| STD\_HR | 6.04 ± 1.55 | 6.00 ± 2.03 | 6.56 ± 2.50 | 6.27 ± 2.00 | 6.71 ± 2.44 |
| ES |  | -0.02 (Trivial) | 0.33 (Trivial) | 0.14 (Trivial) | 0.08 (Trivial) |
| MRR (ms) | 799.97 ± 70.90 | 706.92 ± 82.98\* | 747.50 ± 43.78 | 777.47 ± 46.19 | 820.16 ± 38.71 |
| ES |  | -1.31 (Moderate) | -0.74 (Small) | -0.74 (Small) | 0.28 (Trivial) |
| MHR | 76.06 ± 6.91 | 86.38 ± 10.73\* | 81.08 ± 4.74 | 77.95 ± 4.55 | 73.95 ± 3.72 |
| ES |  | 1.49 (Moderate) | 0.72 (Small) | 0.27 (Trivial) | -0.30 (Trivial) |
| PNN50% | 28.56 ± 11.94 | 9.22 ± 7.49\* | 14.46 ± 9.56 | 18.65 ± 12.17 | 25.71 ± 10.00 |
| ES |  | -1.61 (Moderate) | -1.18 (Small) | -0.82 (Small) | -0.23 (Trivial) |

RMSSD = standardized deviation of differences between adjacent normal R-R intervals; SDNN = standard deviation of all normal R-R intervals; STD\_HR = standard deviation of heart rate; MRR = means of all R-R interval. MHR = means of heart rate; PNN50% = percentage of normal R-R intervals; ES = effect size; Baseline; Post-15 = 15-minutes postexercise; Post-30 = 30-minutes postexercise; Post-45 = 45-minutes postexercise; Post-60 = 60-minutes postexercise. \*Statistical difference in compared to baseline.

**DISCUSSION**

The purpose of the present study was to analyze the acute HRV behavior after 10 RM test load for BS, LP, LE and LF in normotensive subjects. Result’s indicates that normotensive females recovered their baseline values within 15-minutes after 10 RM effort. This finding confirms the initial hypothesis which suggested 10 RM load test would promote a cardiovascular stress and recover in 60-minutes or less. The results of this support previous findings, which observed similar response for moderate (70% of 1 RM) loads (14,15).

Although 1 RM test is conventionally recommended for testing muscle force, it has relevant practical application limitations for your loads percentage. For example, it is possible performed a large number of repetitions and discrepancy when compared to different muscle group sizes and training level (21). Therefore, it is important that safety exercise parameters be investigated in different load tests (i.e. cardiac autonomic modulation). In the present investigation increases in sympathetic activity was observed in recovery moments. Regarding blood pressure behavior, even post-exercise indicates no difference, results should not be neglected since the drop could happen at a moment where the blood pressure was higher (1). Likewise, sympathetic activity was elevated and subsequent HRV reduced, which consequently reduced the cardiac vagal tone. This fact may reduce the autonomic cardiac protection at that time. Sympathovagal balance tends to favor of growing sympathetic predominance and may be associated with cardiovascular injuries. The highest sympathetic activity occurred at 15-minutes postexercise which can be explained by some mechanisms. For example, high intensity RT-exercise stimulates fast-twitch muscle fiber that have great non-aerobic glycolytic capacity and produces high amounts of lactate. Lactate release on blood stimulates exercise pressor reflex through afferent fibers.

The control of cardiac function is mediated from an intrinsic complex and well-structured system involving the participation of afferent and efferent pathways for driving stimuli to the central nervous system and peripheral responses. Structures such as vertebral column, vagus nerve, dorsal root ganglia, brainstem, hypothalamus, thalamus, amygdala and cerebral cortex participate in this process. Afferent nerve fibers (type 3 - myelinated, type 4 - amielinized) are present during exercise, which are sensitive to mechanical and metabolic stimuli, respectively. These fibers have a relevant participation in the control of variables such as blood pressure and heart rate during exercise; that’s is, depending on the exercise intensity may influence metabolic markers such as lactacidemia and ph and consequently, the feedback process that will impact on cardiovascular modulation effects such as HRV. Also, catecholaminergic signaling, hydrogen ions and other metabolites release by exercise stimulate sympathetic activity (26,27). Finally, it seems that exhaustive efforts cause imbalance in the redox balance (18), produces superoxide and this interacting with nitric oxide form peroxynitrite. Peroxynitrite causes a deleterious effect on the vascular endothelium and reduces the availability of nitric oxide, which consequently does not exert a vasodilatory effect (38). A lower availability of nitric oxide may compromise sympathetic regulation, since an imbalance between nitric oxide and angiotensin II may impact the vasomotor center responsible for sympathetic discharges to the vascular tree (19,38). Thus, an exacerbated sympathetic activity may have an impact on the behavior of HRV. Although the present study did not measure markers of oxidative stress, such a hypothesis seems to consistently confirm our findings.

In 10 RM test characteristics, subjects performed a maximum effort on last attempt wherein in previous attempts the load is self-suggestive and submaximal. As such, the fact of no HRV post effort increase may be linked by exercise intensity. Thereby, the flattening of postexercise sympathetic response may not been sufficient and a compensation in sympathovagal balance in favor of parasympathetic activity occurs (28). However, Lima et al. (23) analyzed the effect of different load intensities (50% and 70% of 1 RM) on HRV acute responses and observed a dose-dependency of R-R intervals and HF decreases for higher intensities (70% > 50%). In contrast, LF increased in 70% compared to 50% illustrating that intensities used by authors not able to denote HRV increases. Additionally, training volume can influence the behavior of HRV during RT (14,15). The volume performed by subjects was not standardized because it was a test. That is, a number of subjects may have found the 10 RM load in less trials (sets) when compared the others. Rezk et al. (31) observed the behavior of HRV after RT and regardless of intensity found significant increases in sympathetic activity postexercise. Thus, the results denote a greater relevance for training volumes when compared to RT-intensities. Anunciação et al. (3) investigated the HRV behavior post singles sets (traditional and circuit) and multiple sets (circuit) performed in 18 repetitions with 40% of 1 RM. The results agree with current literature and indicate a dose-dependency volume/intensity. For example, higher volumes (3 sets) and lower recovery (circuit) promotes higher LF/HF ratio, which indicates a higher postexercise sympathetic activity and cardiovascular stress.

There are a few limitations and delimitations to bear in mind when interpreting the results of this present study. Although male produce more muscle force (29), females are less fatigable during dynamic contractions (22). So, the results cannot extrapolate to males. Still, the 10 RM load test pace was not controlled for. This can be considered as both a limitation and strength of this design. Specifically, the lack of control reduces the internal validity of the results, as the duration of each muscle phase contraction could possibly influence the outcome. Conversely, the freedom to choose the pace duration enhances to ecological validity of the findings, as it better represents real-life training scenarios. Anyway, the pace control of movement should be controlled by the intensity of the load, since more intense loads do not allow for slow movements.

In conclusion, although participants work with maximum intensities, 10 RM test are safe for cardiovascular healthy individuals and this fact is confirmed by the results described in the present study. Even increasing sympathetic activity during 10 RM test does not maintain an exacerbated postexercise sympathetic activity. Literature needs further research about this topic. As a practical application, these results can encourage exercise practitioners to do maximum load tests to RT load prescription.

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