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## Exercise type affects cardiac vagal autonomic recovery after a resistance training session

--Manuscript Draft--

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<b>Abstract:</b>	<p>Resistance training sessions involving different exercises and set configurations may affect the acute cardiovascular recovery pattern. We explored the interaction between exercise type and set configuration on the postexercise cardiovagal withdrawal measured by heart rate variability and their hypotensive effect. Thirteen healthy participants (10RM bench press: 56±10kg; parallel squat: 91±13kg) performed six sessions corresponding to two exercises (Bench press vs Parallel squat), two set configurations (Failure session vs Inter-repetition rest session) and a Control session of each exercise. Load (10RM), volume (5 sets) and rest (720 s) were equated between exercises and set configurations. Parallel squat produced higher reductions in cardiovagal recovery versus Bench press (<math>p=0.001</math>). These differences were dependent on the set configuration, with lower values in Parallel squat versus Bench press for Inter-repetition rest session (<math>1.816\pm0.711</math> vs <math>2.399\pm0.739</math> Ln HF/IRR2 x104, <math>p=0.002</math>), but not for Failure session (<math>1.647\pm0.904</math> vs <math>1.808\pm0.703</math> Ln HF/IRR2 x104, <math>p&gt;0.05</math>). Set configuration affected the cardiovagal recovery, with lower values in Failure session in comparison with Inter-repetition rest (<math>p=0.027</math>) and Control session (<math>p=0.022</math>). Postexercise hypotension was not dependent on the exercise type (<math>p&gt;0.05</math>) but was dependent on the set configuration, with lower values of systolic (<math>p=0.004</math>) and diastolic (<math>p=0.011</math>) blood pressure after the Failure session but not after an Inter-repetition rest session in comparison with the Control session (<math>p&gt;0.05</math>). These results suggest that the exercise type and an Inter-repetition rest design could blunt the decrease of cardiac vagal activity after exercise while exercising to muscular failure</p>

	may contribute to the onset of postexercise hypotension.
<p><b>Response to Reviewers:</b></p>	<p>Reviewer #2:</p> <p>This research examined the effect of exercise modality and set-configuration on cardiac vagal autonomy following resistance training. The study was generally well-designed study with obvious attention to the methodology employed. While the paper overall does make a unique contribution to the literature, there are some concerns. A major issue is that the manuscript needs a significant edit to rectify the many errors of grammar throughout (all sections). Further, the discussion is relatively weak in comparison to the remainder of the paper. Finally, the power of the statistical analysis is not strong and one questions whether the discussion/conclusions can be made with any certainty. Further detailed comments on these and other issues are included below.</p> <p>We really appreciate these comments. We have tried to attend all of your suggestions for improving the manuscript. In this regard, the paper has been reviewed by a native English speaker. We have also tried to strengthen the discussion and precise the conclusions.</p> <p><b>Introduction</b></p> <p>The authors should consider improving the flow of this section. I would suggest swapping the order of the 2nd and 3rd paragraphs and focus on enhancing the development of the rationale for the research between paragraphs.</p> <p>We have improved the flow of the introduction and have swapped the order of the paragraphs.</p> <p>There are grammatical errors throughout this section, for example the last sentence on page 3 requires rewording.</p> <p>We have checked the grammar and amended the errors throughout the manuscript.</p> <p><b>Methods</b></p> <p>Page 4, line 18: I am not sure it is accurate to describe all sessions as having the same intensity? By definition, the 'failure' protocol would be more intense that the 'inter-repetition' protocol. Perhaps use 'load' instead.</p> <p>We agree with the reviewer. We have changed "intensity" to "load" throughout the manuscript.</p> <p>Page 5, first sentence: remove (this has been mentioned on the previous page).</p> <p>We have removed this sentence.</p> <p>Page 5: Was the bench press grip width standardised? Why was there a pause in the bench press, but not the squat?</p> <p>The grip width for the bench press exercise was set at 130% of biacromial breadth. The pause between eccentric and concentric was used to eliminate the rebound effect and obtain more consistent measures. This information was added to the description of the bench press exercise paragraph on the methodology section as follows: "Approximately 1 sec. was waited before the start of the concentric phase to eliminate the rebound effect and to obtain more consistent measures. Participants performed the concentric phase as fast as possible. The grip width was set at 130% of biacromial breadth."</p> <p>Page 5, Line 38, 53: What is the 'intended maximal velocity'? If the participants were instructed to move the bar "as fast as possible" then those instructions should be included. 'Explosive' is not a clear descriptor.</p> <p>We have changed "intended maximal velocity" to "as fast as possible" throughout the manuscript.</p> <p>Page 7, Line 40: Change "Previously to exercise," to "Prior to the warm-up,"</p> <p>This change has been addressed.</p> <p>Page 7, Line 47: Remove "after for" and replace with "post exercise for"</p>

We have changed this point.

#### Statistical Analysis

Page 8, line 18: Remove "are shown" and replace with "were calculated"

We have amended this issue.

Page 8: As mentioned previously, the power calculation does not give great confidence in the capacity of the analysis (50-60% of the time) to correctly reject the null hypothesis. 80% power analysis yields a sample size of approximately 25 participants. This is a major weakness of the paper limiting its potential impact.

The reviewer is correct about the limit of the power analyses. Nevertheless, we must stress that the fact of observing significant differences in a sample of thirteen participants reflect that there was a big effect sizes of both exercise type and set configuration.

#### Results

I think the results are overly long and should be reduced in length. This could be achieved by focussing on the major results/interactions only and leaving the relatively minor interactions to be displayed in the figures.

We have reduced the results, focusing on the more important data.

All data should be reviewed with respect to the number of decimal places presented. For example, on page 9, the number of repetitions should only be reported to 1 decimal place at most (and perhaps even no decimal place?).

We have reviewed the manuscript to properly adjust the number of decimals.

Page 10: Notwithstanding the first point above, the authors should take care to ensure the reader at all times is clear about what data is being discussed. For example, line 16, it should be clear that HRV is being discussed (same with the following paragraphs).

We have specified that analysis of interactions were about the  $\ln HF/IRR2 \times 104$  throughout the paragraphs.

#### Discussion

The grammar and scientific writing/expression needs improvement throughout the discussion. The writing could be more focussed around the findings and the impact of the results.

The tables and figures should be referred to throughout the discussion.

We have revised and corrected the whole manuscript. Also, a native English speaker checked the document. In addition, we focused the discussion on the findings and the impact of the results in the new version of the document. At least, we referred the tables and figures throughout the discussion.

We have explained the findings and the impact of the results of the study on page 15 as follows:

"After resistance exercise there is a reduction in the vagal control of the heart (16,21,31,32,37). This reduction in cardiac vagal activity may mean a transient harmful effect in individuals with increased cardiovascular risk due to an augmented probability of suffering a sudden cardiac death mediated by reductions in vagal activity up to 30 min after exercise has been completed (1). Therefore, the usefulness of controlling the loading parameters in order to minimize this reduction in cardiac vagal control may be dependent on the exercise type, the set configuration and the interaction between them. It seems that exercises performed in a lying position, with less muscle mass implicated and done with a short set configuration as the inter-repetition rest design may reduce the loss of vagal control of the heart. In turn, this may guarantee a more secure workout in individuals with increased cardiovascular risk."

"Taking this into account, long set protocols leading to failure may have practical applications as a non-pharmacological therapy in hypertensive individuals to reduce blood pressure. In this regard, muscular failure per se, with all the rest loading parameters equated between protocols, appears to have an important role in the onset

on postexercise hypotension.”

Page 13, Line 11: Did this research (reference 13) normalise for intensity/volume etc? The authors need to be careful here, on page 12 you claim intensity has been controlled yet on page 13 you are arguing a greater glycolytic involvement (ie greater intensity?) with the squat versus the bench press. I think this can be solved with correct terminology.”

The reviewer is correct. The reference 33 was normalized for the same load. We have changed the term “intensity” by “load” throughout the manuscript.

Page 13, Line 22: Remove the word 'members'

We have changed “members” by “limbs” throughout the manuscript.

Page 14, Line 2: What does "cardiac risk" refer to?

After resistance exercise exists a reduction in the vagal control of the heart that may mean a transient harmful effect in individuals with pathological conditions, since 30 min after exercise exists an increased chance of suffering a sudden cardiac death due to a reduction in vagal activity (Albert et al., 2000. PMID: 11070099). We have explained this issue on methodology section on page 15 as follows:

“After resistance exercise there is a reduction in the vagal control of the heart (16,21,31,32,37). This reduction in cardiac vagal activity may mean a transient harmful effect in individuals with increased cardiovascular risk due to an augmented probability of suffering a sudden cardiac death mediated by reductions in vagal activity up to 30 min after exercise has been completed (1). Therefore, the usefulness of controlling the loading parameters in order to minimize this reduction in cardiac vagal control may be dependent on the exercise type, the set configuration and the interaction between them. It seems that exercises performed in a lying position, with less muscle mass implicated and done with a short set configuration as the inter-repetition rest design may reduce the loss of vagal control of the heart. In turn, this may guarantee a more secure workout in individuals with increased cardiovascular risk.”

Table 1: Some of these data should not be reported to 2 decimal places of accuracy. N should also be included.

We have reported the data with the appropriate number of decimals. We have also reported the N in the legend of all the tables.

Figure 1 and 2:

The way the figures are presented may mis-represent the data. For example, the difference in time between 'pre' and '20-25', is not the same as the distance between '20-25' and '25-30'. Perhaps use a bar chart or disconnect 'pre' from the next data point so it is clear it occurred at a different time.

Replace "moments" with Time

We have presented the data disconnecting the post-values from the pre values. In addition, we have replaced “moments” by “time”.

Figure 3

There appears to be no title for figure 3?

N should be included for all figures.

We have added the title for Figure 3. Also, we have reported the N in the legend of all the tables.

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Reviewer #3: Exercise type affects cardiac vagal autonomic recovery after a resistance training session--JSCR-08-6392

General comments: The participant size and methods used in the study are sound, although I question the use of young, healthy participants for a study such as this. I ask the authors to consult the comments listed below:

We really appreciate the previous comments. We have explained the rationale for using healthy participants in the specific comments.

Specific comments:

If word count allows, Abstract would benefit from notation of fitness status of the participants as well as methods used to assess autonomic function. Did PEH occur, as results only state that it was not mode dependent? I would also appreciate some data in the Abstract vs. only p values, which leave the reader in my view starving for actual numbers.

We have restructured the information and added to the abstract the fitness status of the participants, the methods used to analyze autonomic control and we have also reported values of the interaction between exercise type and set configuration. In addition, we have explained that the PEH is affected by the set configuration.

Introduction:

I think the first sentence or two of the Introduction (page 2, lines 6-11) needs strengthening. You state that resistance training has important health benefits yet your transition into mentioning vagal control is a little lacking. Why is this important for persons with a normal BP response such as your subjects, as well as individuals with hypertension, etc.? Overall, why is this study of interest to athletes, coaches, clinicians, practitioners, and scientists who use resistance training in their clients?

Last part of this section: how does this topic apply to practitioners? Why is this area important to clarify?

We have explained the questions demanded in a point by point basis:

•We have strengthened the introduction on page 3 as follows:

“Nevertheless, previous studies have revealed, through heart rate variability (HRV), that resistance training does not improve the autonomic control of the heart (4,5).

Additionally, resistance exercise sessions provoke an acute reduction in the cardiac vagal control (16,21,31,32,37) that can be interpreted as a transient harmful effect in diseased individuals. This is due to that 30 min after exercise there is an increased probability of suffering a sudden cardiac death due to decreased vagal activity (1).”

•We have explained the rationale of the participants selected in discussion section on page 16:

“The present study, using a healthy young population, makes the first attempt to explore the possible implications of exercise type and set configuration on participants with increased cardiovascular risk. Futures studies should focus on analyzing the applicability of these findings on diseased individuals.

•At last, we have specified the practical applications and the interest of the study in the introduction section on pages 3 and 4 as follows:

“In this sense, the effect of the features of the exercises performed (i.e., type of exercise, body position) and the loading parameters (i.e., load, volume) of those exercises, are not adequately understood (20). Coaches and practitioners should know the precise effects of the resistance training factors that affect the cardiac control after resistance exercise in order to modulate the cardiac impact and prescribe exercise in an accurate and safe way. Specifically, resistance exercise should be prescribed in a harmless manner in certain individuals with cardiovascular risk. In order to solve this issue, the effects on the cardiac control should be fully elucidated. “

“A recent study has shown a relationship between the postexercise hypotension caused by resistance exercise and long-term blood pressure reduction at rest (38), making exercise an interesting non-pharmacological therapy to reduce blood pressure. Nevertheless, the loading parameters that affect postexercise hypotension are not completely established. “

“In this regard, our aim was to identify the exercise type and set configuration in which the cardiac autonomic control is less affected, and the possible interaction between these factors. This may have practical applications to prescribing resistance exercise in individuals with elevated cardiovascular risk. Also, we aim to elucidate the implication of the exercise type and the set configuration on the onset and magnitude of the postexercise hypotension in order to prescribe resistance exercise as a non-pharmacological therapy to reduce blood pressure in hypertensive individuals.”

Method:

Participants- was supplement use screened, such as caffeine containing products which can increase BP and potentially minimize PEH onset (Astorino et al. 2012 Res Sports Med)? Page 5 states that this was requested, but how was this actually confirmed prior to each visit?

Participants were encouraged to respect the guidelines, and not to consume any product that may contain caffeine, and to follow normal dietetic habits. No one was using nutritional supplements at the time of the study. We checked the day of the sessions that the BP was not  $\pm 5$  mmHg in comparison with prior sessions. Also, off-time analysis revealed that BP prior to the warm-up were not different between experimental session, suggesting that the basal BP values were always the same. We have added the exclusion of nutritional supplements to the list of substances refrained in the procedures paragraph of methodology section as follows (page 6):

“During the course of the experiment testing, participants were asked to refrain from alcohol, caffeine, nutritional supplements, nicotine, and exercise for 24 hours prior to testing and to fast for three hours prior to the beginning of each session”.

Were all men used in this study normotensive? Aren't there data showing that PEH, for example, is more common in people with hypertension vs. normotension? Please explain.

All participants were normotensive following the JNC 7 (Chobanian et al., 2003), as explained in methodology. Data can be checked at Table 1. The reviewer is right, HTN has a great magnitude of PEH in comparison to NT. Nevertheless, our study makes a first approach to this issue allowing to explore some training variables that could be of interest for a better designing of a strength training routine in diseased individuals. We agree with the reviewer about the need of further studies to confirm our results in people with pathological profiles. We have explained this issue in the discussion section as follows (page 13):

“The present study, using a healthy young population, makes the first attempt to explore the possible implications of exercise type and set configuration on participants with increased cardiovascular risk. Futures studies should focus on analyzing the applicability of these findings on diseased individuals.

Results page 9: there are many terms and abbreviations used here which are unclear; please see below:

'cluster' session? Ln? IRR? Please make sure these are better explained in the method section.

We have eliminated this error and changed “cluster” by “Inter-repetition rest design” throughout the manuscript. We have also added the abbreviation “Ln” to the log transformed process in the statistical analysis paragraph. At last, we have specified that IRR refers to the R-R interval in the data analysis paragraph. These changes can be observed on methodology section as follows (pages 9 and 10):

“Data were log transformed (Ln) in the case that the normality assumption was violated. “

“To weaken the HRV dependence on HR, HF was divided by the squared R-R interval (IRR<sup>2</sup>) of each epoch (13,31).”

Autonomic data: is there any way this section can be condensed? As it currently stands, it seems to be quite repetitive and stricken with p value after p value rather than some actual data showing the results. Please consider changing this to improve understanding for the reader.

We have reduced the results focusing on the more important data and trying to reduce the p values info.

Lastly, it is evident that English is not the authors' first language. Although the submission is quite complete and relatively well-written, I recommend that the authors consult with an individual who can help them identify select portions of text where the grammar is a little inaccurate and/or awkward.

We have revised and corrected the whole manuscript. Also, we have consulted to a native English speaker that checked the manuscript.

Exercise type affects cardiac vagal autonomic recovery after a resistance training session

Running title: Exercise type and cardiac vagal autonomic recovery

Keywords: Cardiac vagal autonomic control; Muscle mass; Set configuration; Resistance Exercise

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## Exercise type affects cardiac vagal autonomic recovery after a resistance training session

Abstract: Resistance training sessions involving different exercises and set configurations may affect the acute cardiovascular recovery pattern. We explored the interaction between exercise type and set configuration on the postexercise cardiovagal withdrawal measured by heart rate variability and their hypotensive effect. Thirteen healthy participants (10RM bench press:  $56\pm 10\text{kg}$ ; parallel squat:  $91\pm 13\text{kg}$ ) performed six sessions corresponding to two exercises (Bench press vs Parallel squat), two set configurations (Failure session vs Inter-repetition rest session) and a Control session of each exercise. Load (10RM), volume (5 sets) and rest (720 s) were equated between exercises and set configurations. Parallel squat produced higher reductions in cardiovagal recovery versus Bench press ( $p=0.001$ ). These differences were dependent on the set configuration, with lower values in Parallel squat versus Bench press for Inter-repetition rest session ( $1.816\pm 0.711$  vs  $2.399\pm 0.739$  Ln HF/IRR<sup>2</sup>  $\times 10^4$ ,  $p=0.002$ ), but not for Failure session ( $1.647\pm 0.904$  vs  $1.808\pm 0.703$  Ln HF/IRR<sup>2</sup>  $\times 10^4$ ,  $p>0.05$ ). Set configuration affected the cardiovagal recovery, with lower values in Failure session in comparison with Inter-repetition rest ( $p=0.027$ ) and Control session ( $p=0.022$ ). Postexercise hypotension was not dependent on the exercise type ( $p>0.05$ ) but was dependent on the set configuration, with lower values of systolic ( $p=0.004$ ) and diastolic ( $p=0.011$ ) blood pressure after the Failure session but not after an Inter-repetition rest session in comparison with the Control session ( $p>0.05$ ). These results suggest that the exercise type and an Inter-repetition rest design could blunt the decrease of cardiac vagal activity after exercise while exercising to muscular failure may contribute to the onset of postexercise hypotension.

Key words: cardiac autonomic control; Exercise type; Set configuration; Resistance exercise



## Introduction

Resistance training is considered a promising intervention to prevent and improve several musculoskeletal, metabolic and cardiovascular conditions (17). Nevertheless, previous studies have revealed, through heart rate variability (HRV), that resistance training does not improve the autonomic control of the heart (4,5). Additionally, resistance exercise sessions provoke an acute reduction in the cardiac vagal control (16,21,31,32,37) that can be interpreted as a transient harmful effect in diseased individuals. This is due to that 30 min after exercise there is an increased probability of suffering a sudden cardiac death due to decreased vagal activity (1). In this sense, the effect of the features of the exercises performed (i.e., type of exercise, body position) and the loading parameters (i.e., load, volume) of those exercises, are not adequately understood (20). Coaches and practitioners should know the precise effects of the resistance training factors that affect the cardiac control after resistance exercise in order to modulate the cardiac impact and prescribe exercise in an accurate and safe way. Specifically, resistance exercise should be prescribed in a harmless manner in certain individuals with cardiovascular risk. In order to solve this issue, the effects on the cardiac control should be fully elucidated. In this regard, cardiac vagal control after a resistance training session has been shown to be affected by load (23,27) and volume (7), although others have not confirmed these findings (2,21).

Other variables that may affect the cardiac autonomic control after resistance exercise are, on the one hand, the type and features of the exercise used, and on the other hand, the set configuration employed. The type and features of the exercise used refer to the muscle mass of the exercises performed and the body postures associated in those exercises. In this sense, exercises with a higher muscle mass involvement produce higher lactatemia (34), and the glycolytic involvement is related to the cardiac vagal withdrawal (27,36). To the best of our knowledge, only one study has analyzed the effect of the exercises type (i.e. upper versus lower limbs) on the cardiovagal control without detecting significant differences

1 between protocols (21). Nevertheless, the exercises were performed to muscular failure and the position  
2 of the exercises was always seated, variables that may have eliminated the differences between protocols.  
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8 Besides the effect of exercise type, the set configuration could also affect the vagal recovery to resistance  
9 exercise. Set configuration refers to the repetitions actually performed with regard to the maximum  
10 possible number of repetitions in a set. Set configuration is closely associated with intensity and volume,  
11 and affects the mechanical performance and the metabolic response to exercise (19,34). Short set  
12 configurations such as the inter-repetition rest design (12,19) result in a higher mechanical performance  
13 and lower involvement of the glycolytic energy system than long set configurations, close or leading to  
14 muscular failure (34). As was explained before, the involvement of the glycolytic energy system during  
15 resistance exercise seems to be related to the changes in the postexercise cardiac vagal control (27,36).  
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17 However, only one study has explored the effects of the set configuration on the cardiac vagal control  
18 (18). That study showed that the reduction of the vagal control of the heart after a resistance exercise was  
19 similar between sets performed to muscular failure and an inter-repetition rest set configuration. However,  
20 in that study only the parallel squat exercise was analyzed and thus, it remains to be explored whether  
21 those results can be replicated with different exercises. It is likely that these inconsistent results could  
22 result from the interaction between the set configurations and the exercise used in that particular study.  
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43 In contrast with the possible harmful effect mediated by the transient reduction in the vagal control of the  
44 heart, postexercise hypotension is a positive acute effect of resistance exercise that has been extensively  
45 reported in the literature (7,8,24,29,37). A recent study has shown a relationship between the postexercise  
46 hypotension caused by resistance exercise and long-term blood pressure reduction at rest (38), making  
47 exercise an interesting non-pharmacological therapy to reduce blood pressure. Nevertheless, the loading  
48 parameters that affect postexercise hypotension are not completely established. In his sense, it is known  
49 that the volume performed is a key factor to induce postexercise hypotension (7,29). However, the impact  
50 of the exercise type and muscular failure on postexercise hypotension is not conclusive: In regards the  
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1 exercise type, some studies suggest that the hypotensive effect depends on muscle mass engaged in the  
2 exercise (24,29), while others did not support this finding (6,30). In regards muscular failure, postexercise  
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4 hypotension was observed in a protocol leading to failure in comparison with a non-failure design (37),  
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6 suggesting that muscular failure may be an important contributor to this effect. However, the load  
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8 between protocols were not equal, something that have affected the results (8) .  
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14 Therefore, the main objective of this study was to explore the impact of the exercise type and set  
15 configuration on the recovery pattern of cardiac vagal modulation and postexercise hypotension. In this  
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17 regard, our aim was to identify the exercise type and set configuration in which the cardiac autonomic  
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19 control is less affected, and the possible interaction between these factors. This may have practical  
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21 applications to prescribing resistance exercise in individuals with elevated cardiovascular risk. Also, we  
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23 aim to elucidate the implication of the exercise type and the set configuration on the onset and magnitude  
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25 of the postexercise hypotension in order to prescribe resistance exercise as a non-pharmacological therapy  
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27 to reduce blood pressure in hypertensive individuals.  
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33 In order to do that, participants performed six experimental sessions, corresponding to the combination of  
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35 two types of exercises (bench press and parallel squat) with two set configurations (sets leading to  
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37 muscular failure and an inter-repetition rest design) and two control sessions, one for each exercise. All  
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39 sessions had the same load, volume and work-to-rest ratio, allowing for comparisons between exercises  
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41 and set configurations. Our hypothesis is that parallel squat and long set configurations leading to  
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43 muscular failure would produce higher levels of cardiac vagal withdrawal and postexercise hypotension  
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45 than short set configurations utilizing an inter-repetition rest design.  
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## 53 **Methods**

### 54 Experimental approach to the problem

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1 A repeated measures design was performed in order to test the impact of both exercise type and set  
2 configuration on the acute changes of cardiovagal control and blood pressure after a resistance training  
3 session. Thus, participants performed six experimental sessions corresponding to two exercise types  
4 (bench press and parallel squat) and three experimental protocols (a session to muscular failure, an inter-  
5 repetition rest session and a control session). All exercising sessions had the same load, volume and work-  
6 to-rest ratio in order to properly identify main effect and interaction between exercise type and set  
7 configurations.  
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### 19 Participants

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22 Thirteen normotensive male sport science students, with at least 6 months of experience in resistance  
23 training completed this study. They were screened and excluded if they had prior history of cardiovascular  
24 disease, orthopedic pathology, or illness. All participants signed an informed consent form and were  
25 informed they could withdraw from the study at any time. The study was approved by the local  
26 Institutional Ethics Committee. The physical, cardiovascular and functional characteristics of the  
27 participants are shown in Table 1.  
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### 46 Procedures

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49 A repeated-measures design was used in this study. Participants reported to the laboratory on 11 different  
50 days: 5 for orientation procedures and 6 for experimental protocols. During the course of the experiment  
51 testing, participants were asked to refrain from alcohol, caffeine, nutritional supplements, nicotine, and  
52 exercise for 24 hours prior to testing and to fast for three hours prior to the beginning of each session. The  
53 warm-up of each session was composed of 5 min of submaximal treadmill exercise at 70-90% of the  
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1 estimated maximum heart rate, 5 min of joint mobilization and calisthenics, and 2 sets of 10 repetitions  
2 with the 50% of the 10RM load for each exercise.  
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### 8 Orientation sessions 9

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11 Participants were instructed on how to properly perform the bench press and parallel squat in three  
12 familiarization sessions that consisted of five progressive submaximal sets with 10 repetitions. In the  
13 following two sessions, 10 RM was tested to establish reliability. Both exercises were performed using a  
14 Smith Machine (Life Fitness, Brunswick Corporation, USA).  
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24 The bench press exercise was performed with the participants starting with the elbows extended. Then,  
25 the bar was lowered to the chest in a controlled manner. Approximately 1 s was waited before the start of  
26 the concentric phase to eliminate the rebound effect and to obtain more consistent measures. Participants  
27 performed the concentric phase as fast as possible. The grip width was set at 130% of biacromial breadth.  
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37 The parallel squat exercise was performed starting from the upright position with the knees extended, the  
38 feet parallel and placed shoulder width apart, and the barbell resting across the back. Participants then  
39 lowered in a controlled manner until the thigh was horizontal to the floor with the knees at approximately  
40 90° of flexion. Finally, participants recovered the initial position, performing each repetition as fast as  
41 possible. The same researcher provided verbal encouragement in order to incite maximal effort by the  
42 participants.  
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54 A previously reported protocol was employed to obtain the 10RM load (22). 10RM was defined as the  
55 load that a participant was able to lift properly 10 times, but not 11. Participants performed no more than  
56 5 attempts on each exercise with a rest interval of 2–5 min between attempts.  
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### Experimental sessions

Participants completed 4 sessions corresponding to the combination of two types of exercises (Bench press and Parallel squat) and two set configurations: Failure session and Inter-repetition rest session.

Additionally, two Control sessions were conducted as a reference for the Bench press and Parallel squat protocols. The Failure session consisted of 5 sets to failure with the 10RM load and with 180 s of rest between sets (i.e. 720 s of total resting time). Inter-repetition rest session consisted of the same number of repetitions completed in the Failure session, but with the total resting time (i.e. 720 s) distributed between each repetition. Thus, the work-to-rest ratio was equated between set configurations while the load (i.e., 10RM), volume (maximum number of repetitions performed in 5 sets) and rest (720 s) were similar between exercises. The Control session consisted in maintaining the body position of the exercises (i.e. lying on a bench for bench press and standing for parallel squat) during 15 min, but without performing any exercise. The order of exercises and control sessions were randomized. However, since the number of repetitions in the Inter-repetition rest session depended on the volume completed in the Failure session, it was not possible to randomize the order of the set configurations. The number of repetitions performed during the Failure session were different across participant and thus, the rest intervals between each repetition were individualized during the Inter-repetition rest session (25). Participants completed all repetitions in the Inter-repetition rest sessions without muscular failure. The sessions were separated by at least 72 hr and were performed at approximately the same hour of the day ( $\pm 1$  h) by each participant.

### Physiological recording

A portable cardiac monitor (Polar RS800CX, Kempele, Finland) was used for beat-by-beat heart rate (HR) recording. An oscillometric device (Omron MIT Elite Plus, Kyoto, Japan) with proper sized cuff was employed for registering systolic (SBP) and diastolic (DBP) blood pressure before and after every session. Data were obtained 10 min prior and in the period 20-40 min after the exercise with the

participant seated and breathing spontaneously. Data were recorded **in a seated position** at the end of a 20 min resting period after exercise to reduce the effect of the increased respiratory rate on the variables (28).

### Data analyses

Heart rate variability (HRV) was used to estimate the vagal autonomic modulation of the heart. **The** Fast Fourier Transformation method was selected in order to analyze the high frequency activity (HF, 0.15-0.4 Hz) in absolute units. HF is used as an indicator of cardiac vagal modulation (3). Kubios HRV software v2.1 (The Biomedical Signal and Medical Imaging Analysis Group, University of Kuopio, Finland) was used to analyze beat to beat intervals series with an automatic artifact correction (i.e., medium correction level). To weaken the HRV dependence on HR, HF was divided by the squared mean R-R interval (**IRR<sup>2</sup>**) of each epoch (15,33). Thereafter, the resultant of this division was log transformed since HF did not achieve normality, and multiplied by 10.000 to achieve positive parameters and facilitate the understanding of the results. This change in the scale does not modify the mathematical properties of the values.

**Prior to the warm-up**, a 10 **min** period were recorded with the participants resting in a seated position. HRV was obtained in the last 5 **min**, while SBP and DBP were assessed at **min** 8 and 10 of this period. After exercise, variables were obtained in epochs of 5 min across the 20-40 minutes for HRV and at minutes 20, 25, 30, 35 and 40 minutes **postexercise** for SBP and DBP.

### Measurement of dynamic performance

A dynamic measurement device was used (T-Force System, Ergotech, Spain) in order to evaluate the mechanical performance as an indicator of neuromuscular fatigue (35). The propulsive part of the concentric phase of each repetition was analyzed and the mean propulsive velocity (MPV) was averaged to the entire session. The propulsive part of the concentric phase is the portion during which acceleration

1 is greater than the acceleration due to gravity (35). To ensure that there was no learning effect due to the  
2 non-randomization of set configurations, the fastest repetitions of every set configuration and each  
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4 exercise were compared, since the velocity of each load determines the relative load of the exercise (10).  
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## 10 Statistical analyses

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13 All data are reported as mean  $\pm$  standard deviation (SD) except in the figures that are reported as mean  $\pm$   
14 standard error (SE). To establish the reliability of the 10RM test, the Intra-class Correlation Coefficients  
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16 (ICC) with Single Measure Intra-Class correlation were determined (ICC = 0.98 and 0.97 for bench press  
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18 and parallel squat, respectively). Shapiro–Wilk test was used to test normal distribution of the parameters.  
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20 Data were log transformed (Ln) in the case that the normality assumption was violated. A paired t-test  
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22 was used to compare the fastest repetitions of every set configuration (Failure session vs. Inter-repetition  
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24 rest session) within exercises. A 2-way repeated-measures ANOVA (exercise  $\times$  set) was performed to  
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26 compare the number of repetitions performed across the 5 sets within Failure sessions. A 3-way repeated  
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28 measures ANOVA (exercise  $\times$  protocol  $\times$  time) was performed to evaluate the effect and interaction  
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30 between Exercise (Bench press or Parallel squat), Protocol (Failure session, Inter-repetition rest session  
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32 and Control session) and Time (Pre and 20-25, 25-30, 30-35, 35-40 min epochs for HRV; and 20, 25, 30,  
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34 35, and 40 min time-points for SBP and DBP). Multiple comparisons with Bonferroni correction were  
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36 performed when necessary. Analysis of the Effect Size was performed with the partial Eta squared ( $\eta_p^2$ ).  
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38 Statistical significance was established with a p value  $\leq 0.05$ . The data were analyzed using SPSS 17.0  
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40 (SPSS, Inc., Chicago, IL, USA). A post-hoc power analysis was calculated using the G Power software  
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42 (version 3.1.4). Statistical power ( $1-\beta$ ) of a repeated measures ANOVA with 4, 5 and 6 measurements for  
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44 a sample size of 13, a correlation among repeated measures of 0.5 and a medium effect size ( $f=0.25$ ) is  
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46 0.51, 0.56 and 0.62, respectively.  
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## 58 **Results**

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The number of repetitions in the Failure session for the Bench press and Parallel squat were  $32 \pm 5$  and  $34 \pm 6$ , respectively. A significant effect of set was observed with a progressive decrease in the number of repetitions with each subsequent set ( $F_{4,52} = 63.256$ ,  $p < 0.001$ ). Neither main effect of exercise, nor significant interaction between exercises and sets was observed ( $p > 0.05$ ). Rest intervals between each repetition during Inter-repetition rest session for the Bench press and Parallel squat were  $23.6 \pm 4.1$  and  $22.9 \pm 4.6$  s, respectively. To analyze the possible learning effect due to the non-randomization of the set configuration, the fastest repetition of the two set configurations of each exercise was compared. There were no differences in the velocity of the fastest repetition between set configurations for either the Bench press or Parallel squat ( $p > 0.05$ ).

#### Autonomic data

For  $\ln \text{HF/IRR}^2 \times 10^4$ , main effects were observed for Exercise ( $F_{1, 12} = 9.803$ ,  $p = 0.009$ ;  $\eta_p^2 = 0.45$ ), Protocol ( $F_{2, 24} = 8.426$ ,  $p = 0.002$ ;  $\eta_p^2 = 0.413$ ), and Time ( $F_{4, 48} = 8.669$ ;  $p = 0.001$ ,  $\eta_p^2 = 0.419$ ). Significant interactions were observed between Exercise and Time ( $F_{4, 48} = 6.800$ ,  $p = 0.001$ ;  $\eta_p^2 = 0.362$ ), Protocol and Time ( $F_{4, 48} = 9.625$ ,  $p < 0.001$ ;  $\eta_p^2 = 0.445$ ) and Exercise and Protocol ( $F_{2, 24} = 4.448$ ,  $p = 0.0023$ ;  $\eta_p^2 = 0.270$ ).

The interaction between Exercise and Time (Fig. 1) revealed differences between exercises for the period 20-35 min, ( $p \leq 0.001-0.012$ ) with lower values for the Parallel squat. Also, differences between moments were dependent on exercise. For the Parallel squat, values were lower in the period 20-35 ( $p = 0.003-0.044$ ) with respect to the Pre values; meanwhile for Bench press, differences were not observed between measurements. Additionally, no differences were observed in the Pre values between exercises.

The interaction between Protocol and Time (Fig. 2) of  $\text{Ln HF/IRR}^2 \times 10^4$  revealed differences between protocols for the postexercise period. The Control session was significantly higher than the Failure session for the entire postexercise period: 20-40 ( $p \leq 0.001-0.017$ ). Furthermore, differences in comparison with the Pre values depended on the protocol. In the Failure session, lower values were observed in the period 20-30 ( $p=0.003-0.004$ ) in comparison with Pre values, while no differences were observed between moments in Control session or Inter-repetition rest session. Finally, no differences were observed in the Pre values between exercises.

The interaction between Exercise and Protocol (Fig. 3) of  $\text{Ln HF/IRR}^2 \times 10^4$  revealed that differences were observed between exercises for Inter-repetition rest session, with lower values in Parallel squat in comparison with Bench press ( $p=0.002$ ). Also, differences between protocols were observed and dependent on the exercise. For the Parallel squat, lower values were observed for the Failure session ( $p=0.008$ ) and the Inter-repetition rest session ( $p=0.037$ ) in comparison with the Control session. However, for the Bench press lower values were observed in the Failure session with respect to both the Inter-repetition rest session ( $p=0.027$ ) and the Control session ( $p=0.022$ ). In addition, no differences were observed between the Control session and the Inter-repetition rest session for bench press.

\*\*\* Fig. 1\*\*\*

\*\*\* Fig. 2\*\*\*

\*\*\* Fig. 3\*\*\*

#### Hemodynamic data

For SBP, a significant interaction between Protocol and Time was observed ( $F_{8, 96} = 2.186$ ,  $p=0.035$ ;  $\eta_p^2 = 0.154$ ) (Fig. 4a). The Failure session was significantly lower than the Control session at 25 ( $p=0.006$ ), 30

( $p=0.009$ ) and 40 min ( $p=0.017$ ) after exercise. Pre-post comparisons were not significant for any session.

Finally, differences between sessions at baseline were not significant.

For DBP, there was a significant interaction between Protocol and Time ( $F_{8, 96} = 4.253$ ,  $p=0.006$ ;  $\eta_p^2 = 0.262$ ) (Fig. 4b). The Failure session was significantly lower than the Control session for the entire postexercise period (25-40 min,  $p=0.001-0.034$ ). There were not differences between Pre-post comparisons for any protocol. Differences in Pre values were not observed.

\*\*\* Fig. 4\*\*\*

#### Dynamic performance measurements

MPV values showed a significantly lower velocity in the Failure session in comparison with the Inter-repetition rest session for both the Bench press ( $0.28 \pm 0.05$  m.s<sup>-1</sup> versus  $0.40 \pm 0.07$  m.s<sup>-1</sup>,  $p < 0.001$ ) and Parallel squat ( $0.33 \pm 0.4$  m.s<sup>-1</sup> versus  $0.41 \pm 0.1$  m.s<sup>-1</sup>,  $p=0.001$ ) exercises.

#### Discussion

In the current study we explored the effects of the exercise type, set configuration and their interaction on the postexercise cardiovagal withdrawal and the postexercise hypotension. The main findings of this study were a) the type of exercise affected the cardiac vagal autonomic control after a resistance exercise, with less control after parallel squat in comparison with bench press exercise. b) Set configuration also affected the autonomic cardiac vagal control after exercise, with less control in the Failure session in comparison with Inter-repetition rest session and Control session. c) Interactions between the type of exercise and the set configurations revealed that the cardiac vagal control is affected by both factors

1 simultaneously and d) Systolic and diastolic blood pressure after the failure sessions were decreased **with**  
2 respect to **the** control sessions.  
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7 Our study shows that when **load**, volume and work-to-rest ratio are equated, the type of exercise affects  
8 the pattern of recovery of the vagal autonomic control of the heart **(Fig. 1)**. The lower reduction in the  
9 cardiac vagal control after Bench press in comparison with Parallel squat could be caused by the body  
10 positions and muscle masses involved in those exercises. The lying position during the bench press could  
11 facilitate venous return and the cardiac filling of the ventricle during preload, in comparison with the  
12 **stand-up** position during the Parallel squat. In addition, the lower amount of muscle mass involved during  
13 a bench press exercise in comparison with a parallel squat could induce lower glycolytic involvement for  
14 the former. Although lactate was not analyzed in the current study, previous work reported higher levels  
15 of blood lactate concentration during squat in comparison with bench press **with the same load** (34).  
16 Therefore, we can speculate that the low glycolytic involvement during the bench press could blunt the  
17 loss of cardiac vagal control, since previous studies have suggested a relationship between cardiac vagal  
18 withdrawal and lactate levels both at rest with intravenous injection of lactate (9,39) and after resistance  
19 exercises (27,36). To the best of our knowledge, only one study **has** analyzed the effect of the exercises  
20 type (i.e. upper versus lower **limbs**) on the cardiac vagal control without detecting significant differences  
21 between protocols (21). However, both exercises were performed to muscular failure, causing a high  
22 fatigue that could overcome a plausible difference **between** each exercise. **In fact**, in the current study,  
23 when both exercises were performed to muscular failure, no differences were observed between exercises.  
24 These findings suggest that training to muscular failure may provoke a significant and comparable  
25 reduction in vagal control regardless of the type of exercise performed.  
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53 Set configuration also affects the pattern of recovery of the vagal autonomic control of the heart **(Fig. 2)**.

54 Our study shows that Failure session had a higher loss of **cardiac** vagal control in comparison with **the**  
55 Control session and **the** Inter-repetition rest session. Meanwhile, for Inter-repetition rest session the  
56 cardiac vagal control was scarcely affected. Nevertheless, when the type of exercise was taking into  
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1 account, set configuration modulated the cardiac vagal response for Bench press but not for the Parallel  
2 squat (Fig. 3). In regards to the Bench press, the Failure session induced less vagal control than the Inter-  
3 rest repetition session. In the Parallel squat, these differences were not observed. These results for the  
4 parallel squat are in agreement with a previous study comparing a session to muscular failure versus an  
5 inter-repetition rest session for the same exercise (18). The differences observed for set configuration  
6 between bench press and parallel squat may be due to the type and features of the resistance exercise  
7 performed. It is possible that when protocols are performed in exercises that involve large muscle mass,  
8 the loss in cardiac vagal control is comparable regardless of the set configuration employed.  
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21 After resistance exercise there is a reduction in the vagal control of the heart (16,21,31,32,37). This  
22 reduction in cardiac vagal activity may mean a transient harmful effect in individuals with increased  
23 cardiovascular risk due to an augmented probability of suffering a sudden cardiac death mediated by  
24 reductions in vagal activity up to 30 min after exercise has been completed (1). Therefore, the usefulness  
25 of controlling the loading parameters in order to minimize this reduction in cardiac vagal control may be  
26 dependent on the exercise type, the set configuration and the interaction between them. It seems that  
27 exercises performed in a lying position, with less muscle mass implicated and done with a short set  
28 configuration as the inter-repetition rest design may reduce the loss of vagal control of the heart. In turn,  
29 this may guarantee a more secure workout in individuals with increased cardiovascular risk.  
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45 Set configuration also affects postexercise blood pressure. In the Failure session, both systolic and  
46 diastolic blood pressures were reduced with respect to the Control session. However, after the Inter-  
47 repetition rest session blood pressure remained unaffected and no differences were found in comparison  
48 with the Control session. A possible explanation for this difference may be due to local postexercise  
49 vasodilation in the active muscles after the Failure session due to an activation of histamine H<sub>1</sub> and H<sub>2</sub>  
50 receptors (13). This activation may be a consequence of the metabolic production associated with  
51 muscular fatigue. Postexercise hypotension has previously been observed in protocols leading to muscular  
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1 failure (14,26), even with low volume (26), which suggests that muscle failure is a substantial contributor  
2 to the onset of the hypotensive effect. A previous study (37) compared a muscle failure with muscle non-  
3 failure protocols, and reported a hypotensive effect only in the muscle failure protocol. Unfortunately, in  
4 that particular study the load was not equated. To the best of our knowledge, the current study is the first  
5 study that compares a protocol with failure to a protocol without failure while matching all the loading  
6 parameters. The type of exercise did not affect the blood pressure recovery and did not lead to  
7 postexercise hypotension. This lack of difference between exercises is in agreement with a previous study  
8 (30) that evaluated the effect of muscle mass on postexercise hypotension using a similar volume to the  
9 present study. In addition, the significant DBP elevation observed in the Control session could be  
10 attributed to the orthostatic stress (11). The orthostatic stress is commonly observed in prolonged sitting,  
11 possible due to a baroreflex-mediated raise in total peripheral resistance (11).  
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28 Taking this into account, long set protocols leading to failure may have practical applications as a non-  
29 pharmacological therapy in hypertensive individuals to reduce blood pressure. In this regard, muscular  
30 failure *per se*, with all the rest loading parameters equated between protocols, appears to have an  
31 important role in the onset on postexercise hypotension. The present study, using a healthy young  
32 population, makes the first attempt to explore the possible implications of exercise type and set  
33 configuration on participants with increased cardiovascular risk. Futures studies should focus on  
34 analyzing the applicability of these findings on diseased individuals.  
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45 In summary, the type of exercise affects the cardiac vagal control after resistance exercise, with higher  
46 reductions in Parallel squat in comparison with Bench press. Also, our data showed that the Failure  
47 session caused a loss of cardiac vagal control while the Inter-repetition rest session blunted the impact of  
48 resistance exercise on the postexercise cardiac vagal control. Interactions between the type of exercise  
49 and set configurations showed that the cardiac vagal control after resistance exercise is affected by both  
50 factors simultaneously. Finally, postexercise hypotension was dependent on set configuration, with lower  
51 values of blood pressure after the Failure session but not after the Inter-repetition rest session.  
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### Practical applications

The type of resistance exercise and the set configuration should be carefully selected when prescribing resistance exercise to populations with an increased cardiovascular risk. Exercises with a lying position and less muscle mass involved (i.e. bench press) in combination with shorter set configurations (i.e. inter-repetition rest design) could blunt the increased cardiovascular risk associated with decreased vagal activity after resistance exercise. On the contrary, when the objective of the prescribed resistance exercise is a postexercise reduction in blood pressure, set configurations to failure may be recommendable. It is important to note that one simple exercise with a long set configuration was sufficient to reduce the cardiac vagal control and to provoke the onset of the postexercise hypotension in comparison to a control session.

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4 **Figures legends**  
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6  
7 Figure 1. Interaction between Exercise and Time for the Ln of HF/IRR<sup>2</sup> x 10<sup>4</sup> (n=13).  
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9 In circles, Parallel Squat. In squares, Bench press.  
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11 \* Differences versus Pre values of the same exercise  
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13 # Differences between different exercises  
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15 Data displayed as means ± SE  
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20 Figure 2. Interaction between Protocol and Time for the Ln of HF/IRR<sup>2</sup> x 10<sup>4</sup> (n=13).  
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22 In circles, Control session. In squares, Inter-repetition rest session. In triangles, Failure session.  
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24 \* Differences versus the Pre values of the same protocol  
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26 # Differences versus the Control session  
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28 @ Differences between Inter-repetition rest session  
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31 Data displayed as means ± SE  
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36 Figure 3. Interaction between Exercise and Protocol for the Ln of HF/IRR<sup>2</sup> x 10<sup>4</sup> (n=13).  
37

38 In black, Control session. In dark gray, Failure session. In light gray, Inter-repetition rest  
39 session.  
40

41 \* Differences versus the Control session  
42

43 # Differences versus the Failure session of the Bench Press  
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45 @ Differences versus the Inter-repetition rest session of the Parallel Squat  
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48 Data displayed as means ± SE  
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53 Figure 4. a) Interaction between Protocol and Time for SBP. b) Interaction between Protocol and  
54 Time for DBP. (n=13).  
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56 In circles, Control session. In squares, Inter-repetition rest session. In triangles, Failure session.  
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58 # Differences versus the Control session  
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@ Differences between Inter-repetition rest session and Failure session

% Significant higher versus Pre values

Data displayed as means  $\pm$  SE

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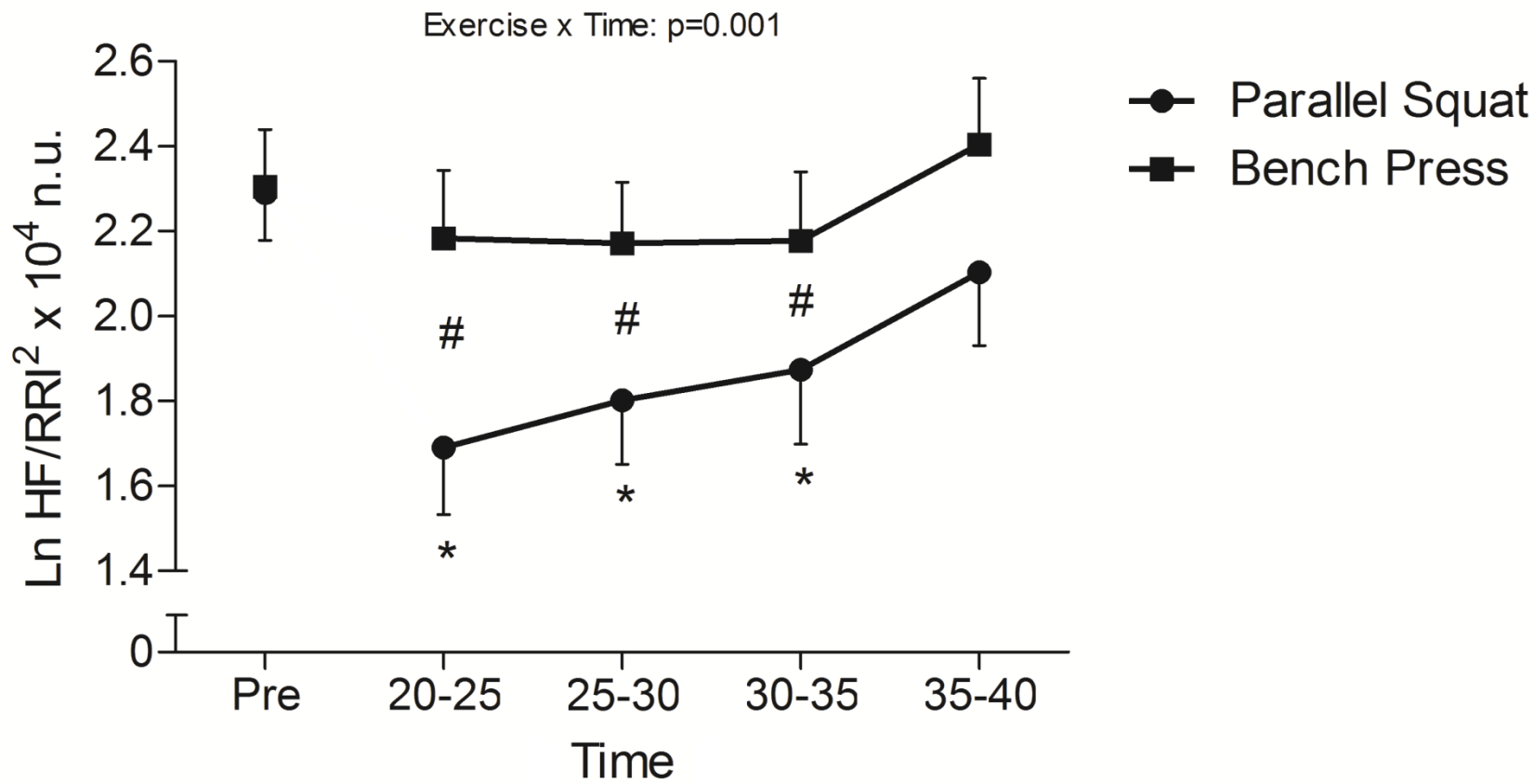
Table 1. Physical, cardiovascular and functional characteristics of the participants

Table 1.	
Age (yr)	23±3
Height (m)	1.76±0.05
Body mass (kg)	72.1±5.8
Body mass index (kg/m <sup>2</sup> )	23.4±1.2
SBP (mmHg)	113±5
DBP (mmHg)	63±6
MAP (mmHg)	79±6
HR (bpm)	54±6
10RM Press (kg)	56±10
10RM Squat (kg)	91±13

Data are means±SD

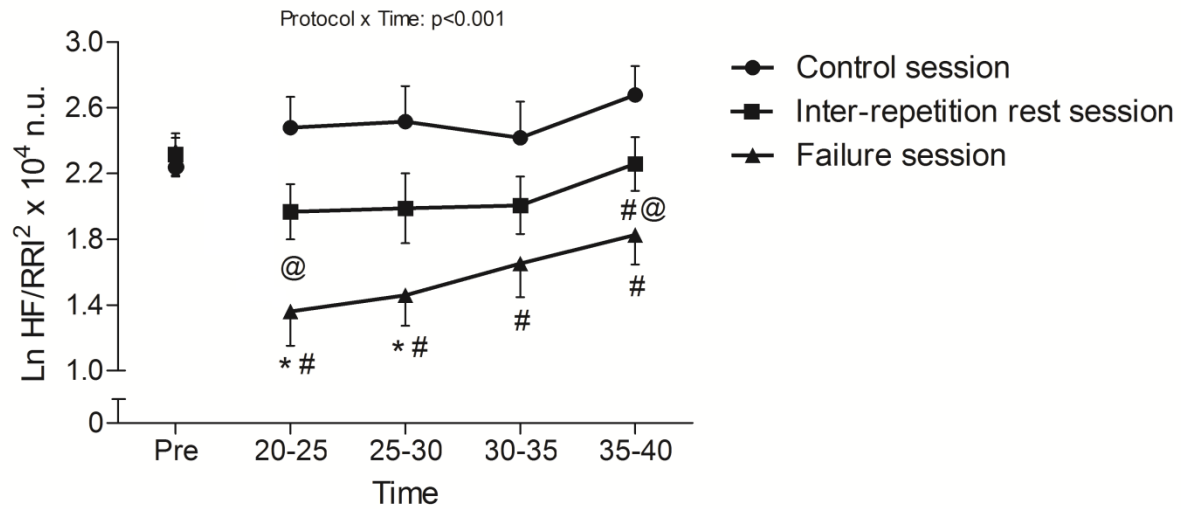
# Figure 1

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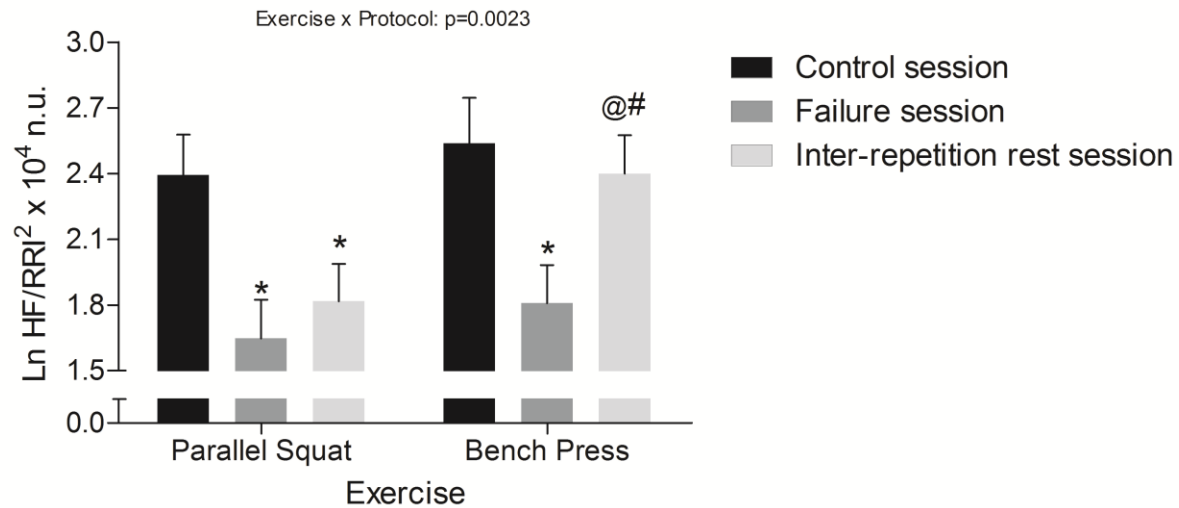
# Figure 2

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# Figure 3

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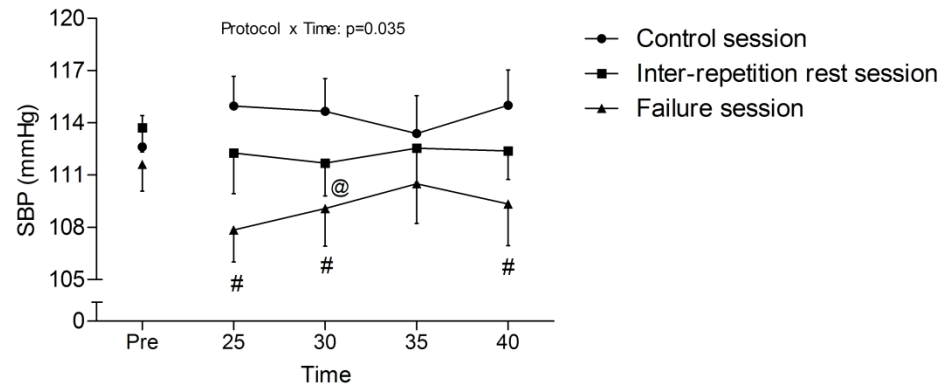




# Figure 4

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a)



b)

