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

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ABSTRACT

International Journal of Exercise Science 11(6): 834-843, 2018. 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 $RMSSD_{ms}$ (p = 0.010; effect size = -1.3), MRR_{ms} (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, maximum repetition (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 volume of RT 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) provides 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 recovery 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). Women 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 times 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.

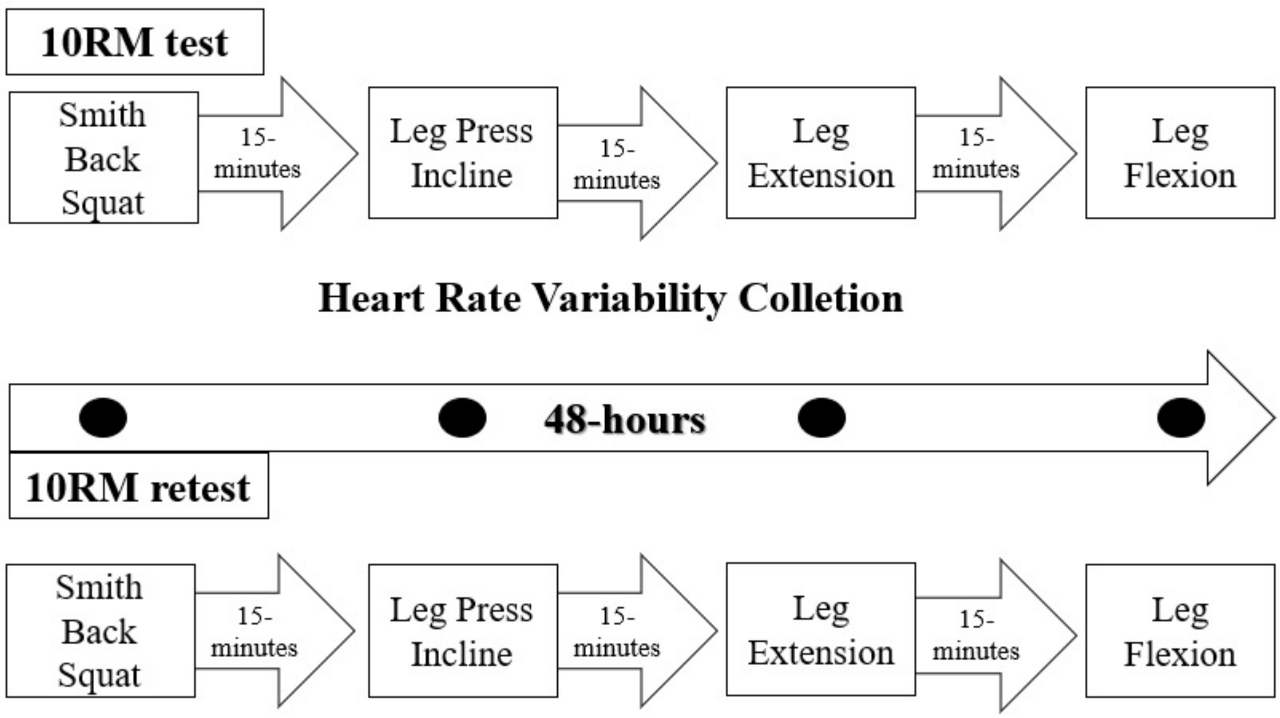

Figure 1. Flowchart representing the experimental study design.

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 were 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), collection 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 (LF_{nu}), high frequency in normalized units (HF_{nu}), LF/HF ratio, standardized deviation of differences between adjacent normal R-R intervals ($RMSSD_{ms}$), standard deviation of all normal R-R intervals ($SDNN_{ms}$) and heart rate (STD_HR), means of all R-R intervals (MRR_{ms}) 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: $ICC = [MS_b – MS_w] / [MS_b + \{k -1\}. MS_w])$, where MS_b = mean-square between, MS_w = 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's 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 reliabilities 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 $SDNN_{ms}$ (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 $RMSSD_{ms}$ (F = 4.470; *p* = 0.010), MRR_{ms} (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 differences 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 recovery 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 estimating load 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 a few 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 released 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 - amyelinized) 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. Exercise intensity may influence metabolic markers such as lacticaemia 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 forms 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 the last attempt, where in previous attempts the load was 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 have 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 males 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 the ecological validity of the findings, as it better represents real-life training scenarios. Regardless, 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 tests are safe for cardiovascular healthy individuals and this fact is confirmed by the results described in the present study. Even increasing sympathetic activity during a 10 RM test does not maintain an exacerbated postexercise sympathetic activity. These results contribute to the literature base on this topic. As a practical application, these results can encourage exercise practitioners to perform maximum load tests to RT load prescription.

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