

## Changes in Heart Rate Variability and Post Exercise Blood Pressure from Manipulating Load Intensities of Resistance-Training

Behzad Alemi<sup>1\*</sup>, Lian-Yee Kok<sup>1</sup>, Hui-Yin Ler<sup>2</sup>, Chen-Soon Chee<sup>1</sup>

<sup>1</sup>Faculty of Educational Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan

<sup>2</sup>Department of Sport Science, Faculty of Applied Sciences, Kolej Universiti Tunku Abdul Rahman, 53300 Kuala Lumpur

**Corresponding Author:** Behzad Alemi, E-mail: Behzad\_alemi@yahoo.com

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### ABSTRACT

**Background:** The isolated effect of resistance training (RT) on heart rate variability (HRV) and blood pressure (BP) is crucial when prescribing suitable training programmes for healthy individuals. **Objective:** The purpose of this study was to compare BP and HRV responses in physically active men after an acute RT session with loads of 5-, 10- or 15-repetition maximums (5RM, 10RM and 15RM). **Method:** Eighty-one men (age: 21.6±1.1yr; body mass: 74.1±5.8 kg; height: 175.3 ±7.1cm) who performed moderate to vigorous physical activities for at least 30 min a day on most days of the week participated in this study. After the of 5RM loads for the bent-over row (BR), bench press (BEP), Dead-lift (DL) and squats (SQ), participants were divided into three training load groups (15RM = GrpL, 10RM = GrpM or 5RM = GrpH). During the experimental session, each group (n=27) performed 3 sets for each of the four exercise, with 2-min rest intervals between sets and exercises with their assigned training load. BP and HRV were measured prior to, immediately after, and at 15-min intervals until two hours post-experiment. **Results:** All three groups attained improved BP ( $p = .001$ ) reductions and longer HRV ( $p = .0001$ ) changes after an acute exercise session but the GrpM (10RM) and GrpL (15RM) performed better than GrpH (5RM). **Conclusion:** Strength and conditioning professionals may prescribe exercises with 10-15RM loads if the aim is to obtain an acute reduction in BP after an RT session.

**Key words:** Systolic Pressure, Diastolic Pressure, Heart Rate Variability, Acute Resistance Training.

### INTRODUCTION

Resistance training (RT) has been suggested as a mode of training for reducing cardiovascular risks (Pescatello et al., 2004). In healthy participants, RT has induced improvement in vagal control of the heart and bradycardia (Gregoire et al., 1996) in addition to reducing blood pressure (BP) via decreases in both systolic and diastolic blood pressure (Collier et al., 2009). It has been reported that small reductions in blood pressure can lower the risks of strokes in both healthy and morbid subjects (ACSM, 2013). The possible mechanism responsible for BP changes after exercise is the activation of the parasympathetic (PNS) and sympathetic (SNS) nervous system. SNS and PNS are part of the autonomic nervous system which controls the body's involuntary internal functions. The autonomic nervous system reactions are measured via the autonomic control of blood circulation and heart rate variability, or HRV (Sztajzel, 2004). HRV has been suggested to be an important indicator of mortality (Kors, et al., 2007). Studies on HRV revealed that coronary heart disease and mortality could be predicted by the amount of

variation of heart rate intervals, with fewer HRV indicating higher risk (Dekker et al., 2000). Moreover, a meta-analysis found positive and significant effects of energy system training on resting parasympathetic outflow as measured through high- (HFnu) and low-frequency (LFnu) power of the HRV analysis and post-exercise BP reduction with the greatest effect reported with longer interventions and younger participants (Hagerman et al., 2000; MacDonald, 2002; Sandcock, Bromley, & Brodie, 2005). Researchers have also found that the HFnu component of HRV and BP remained more depressed while LFnu component rises after RT by comparing the autonomic activity after exercise (Figueiredo et al., 2015; Figueiredo, et al., 2016; Heffernan, Fahs, Shin-sako, Jae, & Fernhall, 2007).

Early investigations into HRV during RT compared 25 min of RT using 10RM for eight RT exercises performed for three sets with 90s rest between exercise and sets to energy system training (Heffernan et al., 2006). Results showed a decrease in HFnu power after RT training. Another study (Heffernan et al., 2007) examined heart rate complexity and heart rate recovery to measure the influence of detraining

and resistance training on cardiac autonomic modulation in healthy young men. They reported that RT have boosted heart rate complexities and heart rate recovery but had no effects on spectral measures of HRV. Furthermore, they noticed that autonomic changes depressed shortly after cessation of training. More recent studies (Figueiredo et al., 2015) examined the effect of three different load intensities (80%, 70% and 60% of 1RM with 8-10 repetitions per set) on BP responses in prehypertensive trained men, and the results revealed significant differences in the duration of the BP reduction when the 70% of 1RM loads were used in a RT session, independent of the total volume. These results demonstrated that moderate to high intensities could result in a longer BP response in trained men. Another study by Figueiredo et al., (2016) recruited a sample of prehypertensive men with 6-month RT experience to perform RT with a rest interval of 1 or 2 min between sets of exercise found that DBP was reduced after performing RT, but there were no SBP changes. Additionally, there were significant changes in HFnu 10 min post exercise for the 1-min rest interval group but no significant difference in LFnu changes after performing three sets of RT with 70% of 1RM. There were also no differences in HRV between the two exercise protocols.

However, since different researchers utilized different load intensities (LI), it is not possible to establish clearly the isolated effects of RT on cardiac autonomic modulation and BP (Chen et al., 2011; Teixeira et al., 2011; Wanderley et al., 2013). In RT, the rest length between each set has a major impact on the metabolic and mechanical responses of the vasculature. This variable also influence the response mechanisms of cardiovascular control that in turn, can affect baroreceptors (Piras, Persiani, Damiani, Perazzolo, & Raffi, 2015). This study attempted to compare BP and HRV responses in trained man with combination of different LI. It was hypothesized that as LI increases a progressive longer BP reduction would ensure in conjunction with reduction in HRV.

## METHODOLOGY

### Participants and Design

The present study used an experimental design with randomized groups. A priori power analysis (G\*power) was performed with power set at .90 and  $\alpha = .05$  and determined that 81 participants (age:  $21.6 \pm 1.1$  yr; body mass:  $74.1 \pm 5.8$  kg; height:  $175.3 \pm 7.1$  cm) were adequate. Inclusion criteria were that they performed moderate to vigorous aerobic exercises or RT according to the physical activity recommendations of the ACSM (2013), and were free from cardiovascular diseases, did not have any physical injuries or acute illnesses and did not take any medication nor smoked six months prior to the study (Nekooei et al., 2019). All participants were volunteers and gave written informed consent before they were tested for 5RM squat (SQ), bench press (BEP), barbell bent-over row (BR) and deadlift (DL). Based on the ranking of their SQ and BEP scores, each participant was then put into one of three groups using the A-B-B-A technique. Each group (n=27) was then randomly assigned a training intensity load

to be performed during one experimental training session. All participants completed the experiment and institutional approval was obtained prior to the commencement of the study.

### Procedures

All participants attended one familiarisation session, followed by 5RM testing for each of the four exercises (SQ, BEP, BR, & DL), with one exercise tested a day and a rest period of at least 48h between each testing session. Following this, the participants were put into one of three groups with a randomly assigned a training intensity load. The group training with 15RM loads was named GrpL, while the groups training with 10RM and 5RM loads was designated GrpM and GrpH respectively. At least 72h after the final testing session, the participants completed an acute experimental training session that incorporated three sets of SQ, BEP, BR and DL in sequential order, using their designated training loads, with 2-min rest intervals between sets. All exercises were performed using free weights and the mass of all weights and barbells used was confirmed using a precision scale (Column Scale Model No. 769, Seca, Germany). The experimental session was preceded by a 10-min warm-up, beginning with a slow jog to raise body temperature, followed by performing light loads of each exercise (10-20% of 5RM load) for 15-20 repetitions. For each load intensity, each participant performed maximal repetitions to concentric failure. No pause was permitted between concentric and eccentric phases of each repetition, and velocity was volitionally controlled. BP (SBP and DBP) and HRV (HFnu and LFnu) were measured after a 10-min passive rest period was enforced upon arrival at the laboratory, and for 120min post-exercise at 15-min intervals.

### 5RM testing

Two days after the familiarization session, the participants performed a 5RM test (ACSM, 2013) for the squat. Initially, participants performed warm up by jogging slowly for 10 min followed by lifting approximately 50% of the predicted 5RM load for 10 repetitions. The testing process begun 2 min after the warm-up. Participants were asked to try to accomplish 5 repetitions with the imposed load in three attempts until the 5RM load was identified. After each attempt, there was 2-5 min rest period. The last resistance lifted five times before failure was recorded as the participant's 5RM load for the squat exercise. The entire process was repeated for each of the other three exercises (BEP, BR, & DL) after 48hr respectively.

### Heart rate variability measurements

HRV was measured using portable heart rate monitors (Polar Team S810i, Kempele, Finland) with storage capacity 30000 R-R intervals and an accuracy of 1ms against an ECG system (Amani, Sadeghi & Afsharnejad, 2018). The R-R intervals were obtained at a sampling frequency of 500 Hz continuously for 20 min and downloaded via Polar software for analysis. The R-R intervals were then split into HF and LF components

using Fourier transformation while noise filtering was reduced through the Kubios HRV Analysis Software (version 2) program (Kempel, Finland). The data were then expressed in normalized units to represent parasympathetic (HFnu) and sympathetic (LFnu) outflow (Tavainen et al., 2014).

### Blood pressure measurements

BP data were obtained using digital sphygmomanometers (SunTech Medical Oscar 2, Morrisville, USA) with an accuracy of approximately 2 mm Hg of reference sphygmomanometers during testing. Intra-subject reliability was assessed to ensure reliability (MacDonald, 2002). For each participant, BP data was averaged over two consecutive measurements, with participants seated and resting for 5 min between measurements.

### Statistical Analysis

Data for all variables are displayed as mean  $\pm$  SD, while a two-way mixed ANOVA was used to examine the independent and dependent variables (SPSS version 22.0, SPSS, Inc. USA). The between-subject factor involved the three load intensities groups GrpL, GrpM and GrpH while the within-subject factors (Time) were measured for nine times repeatedly (3 groups X 9 HRV or BP measurements). Statistically significant interactions were further examined for differences using the Tukey HSD test. The level of significance for all measured variables was set at  $p < .05$ .

## RESULTS

All tested variables were normally distributed. There was no significant difference among all groups for characteristics such as age, height and weight as well as 5RM strength (Table 1).

### Blood Pressure Results

The SBP analysis showed that Box's M statistic was not significant ( $p = .060$ ) and the assumption of homogeneity of variance-covariance was met but the Mauchly's test of sphericity was significant ( $p < .05$ ), and the F-ratio was obtained

using the Huynh-Feldt epsilon (.936). There was a statistically significant interaction between load intensity and time on SBP changes [ $F_{(14.9, 583.1)} = 2.562, p = .001$ ], and a significant reduction in SBP was found at all post-exercise time points when compared to the pre-exercise scores for all three groups. In addition, there was significant difference between GrpL and GrpM with GrpH at 75 min post exercise ( $p = .025$ ) but no difference was observed between GrpL and GrpM. It needs to be highlighted that SBP induced from the 10RM loads in GrpM was the lowest compared to SBP induced on GrpL and GrpH except at 120 min post-exercise (Figure 1). The analysis for DBP was similar to that of SBP with the test of sphericity not met ( $p < .05$ ) and degrees of freedom calculated with the Huynh-Feldt epsilon (.932). There was a statistically significant interaction between load intensity and time on DBP changes [ $F_{(14.9, 581.8)} = 6.287, p = .0001$ ]. Similarly, to SBP, significant reductions in DBP was found at all post-exercise time points when compared to the pre-exercise measure for all three groups. Significant difference between GrpH with GrpL ( $p = .020$ ) and GrpM ( $p = .033$ ) was observed at 105 min post exercise. Unlike SBP however, DBP induced from 15RM loads in GrpL were lowest at all time points except at 15 and 120 min post-exercise (Figure 2).

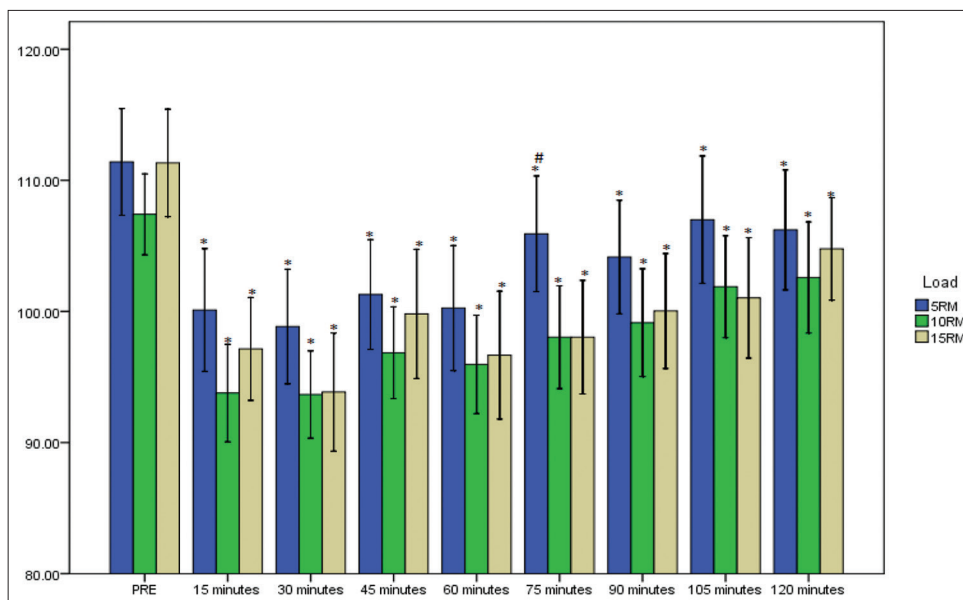
### Heart Rate Variability Results

Box's M statistic was not significant ( $p = .062$ ) and the assumption of homogeneity of variance-covariance was met. The HFnu analysis showed that the Mauchly's test was significant and indicated that the assumption of sphericity has been violated ( $p < .05$ ). Thus, the F-ratio was obtained using the Huynh-Feldt epsilon (.901). There was significant interaction [ $F_{(14.4, 562.3)} = 3.630, p = .0001$ ] between load intensity and time on HFnu fluctuations. Post hoc analysis found significant reduction of HFnu at all post-exercise recovery time points when compared to the pre-exercise score for all three groups (Figure 3). Additionally, there were a significant difference in HFnu between GrpM with GrpH ( $p = .003$ ) and GrpM with GrpL ( $p = .016$ ) with no difference between GrpL at 30min post-exercise. Also, significant difference was found between GrpH with GrpL ( $p = .0001$ ) and GrpM ( $p = .004$ ) at 45 min post exercise but no difference was detected between GrpL and GrpM. Similarly, for the LFnu analysis, Mauchly's

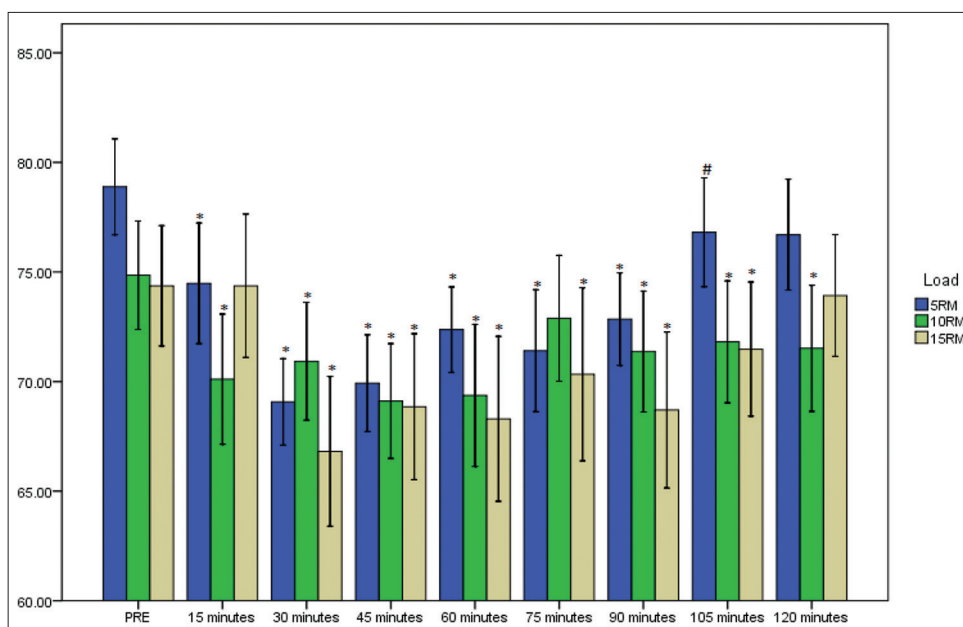
**Table 1.** Biodata, 5RM strength, HRV and BP characteristics of participants

Characteristics	Groups			F	p
	GrpL (n=27)	GrpM (n=27)	GrpH (n=27)		
Age (yr)	21.1 $\pm$ 1.1	20.1 $\pm$ 2.3	22.1 $\pm$ 1.2	0.54	0.82
Height (cm)	175.3 $\pm$ 8.3	174.7 $\pm$ 9.3	176.5 $\pm$ 6.7	0.58	0.79
Weight (kg)	81.7 $\pm$ 5.2	75.4 $\pm$ 4.8	82.5 $\pm$ 3.2	0.28	0.97
Absolute 5RM (kg)					
SQ	84.2 $\pm$ 4.1	91.5 $\pm$ 3.8	87.4 $\pm$ 4.7	1.67	0.12
BEP	56.8 $\pm$ 1.1	55.6 $\pm$ 0.8	59.3 $\pm$ 1.2	1.23	0.29
BR	68.7 $\pm$ 2.5	68.9 $\pm$ 4.9	69.5 $\pm$ 3.2	1.06	0.40
DL	47.5 $\pm$ 1.7	46.6 $\pm$ 1.5	46.7 $\pm$ 1.2	1.45	0.19

GrpL performed 15RM, GrpM performed 10RM, GrpH performed 5RM



**Figure 1.** Systolic blood pressure responses to different load intensities. \*Significant difference from pre-test ( $p < 0.05$ ). # Significant differences between load intensities ( $p < 0.05$ )



**Figure 2.** Diastolic blood pressure responses to different load intensities. \*Significant difference from pre-test ( $p < 0.05$ ). # Significant differences between load intensities ( $p < 0.05$ )

test was also significant and the assumption of sphericity violated (Huynh-Feldt epsilon = .899). A significant interaction [ $F_{(14,3,561.2)} = 3.254, p = .0001$ ] was found between load intensity and time with post hoc analysis showing significant increase in LFnu thought the first 60 min for all intensity groups when compared to pre-test. However, the increase in LFnu was continued until 75 min for GrpM and GrpH groups (Figure 4).

## DISCUSSION

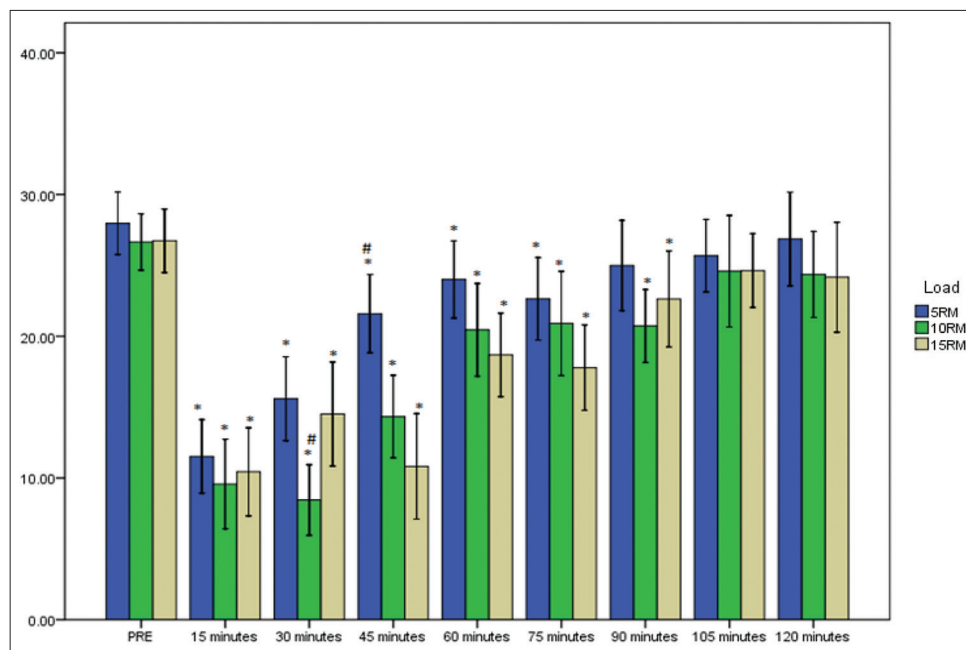
The purpose of this study was to examine the effect of three load intensities on BP and HRV changes after RT in physically active men. The key findings of this study indicated that post exercise SBP and DBP reductions after an

acute RT session with both 15RM and 10RM loads were longer than after training with 5RM loads. Furthermore, HRV changes were also superior with moderate (10RM) and light (15RM) loads, but the effects lasted for a shorter duration compared to BP hypotension.

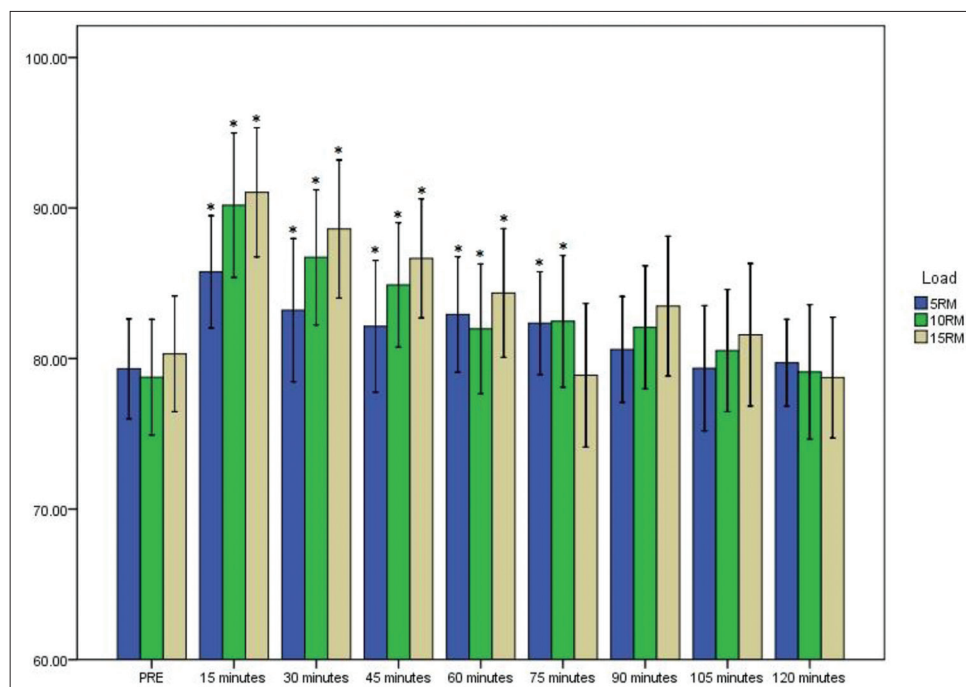
## Blood Pressure Changes

A single acute bout of RT with low (15RM), moderate (10RM) and high (5RM) loads intensities decreased SBP up to 120 min post-exercise. However, SBP and DBP reduction were greater after training with the load intensities of 10 and 15RM. While the 5RM load approximates 85% of 1RM, 10-15RM loads would be closer to moderate load





**Figure 3.** High frequency responses to different load intensities. \*Significant difference from pre-test ( $p < 0.05$ ). # Significant differences between load intensities ( $p < 0.05$ )



**Figure 4.** Low frequency responses to different load intensities. \*Significant difference from pre-test ( $p < 0.05$ )

intensities of 65-76%. These findings are consistent with those of Figueiredo et al. (2015) who examined the effects of 8-10 repetitions of 80%, 70% and 60% of 1RM on BP responses in prehypertensive trained men and found significant differences in the duration of BP reduction when a load of 70% of 1RM was used, independent of the total volume. Another study (Neto et al., 2015) revealed longer SBP and DBP hypotension with moderate rather than light loads of RT when comparing RT training with 80% and 30% of 1RM. These results support current findings that moderate intensity loads resulted in longer BP responses in physically

active men. And results were similar regardless of whether DBP or SBP were analyzed. A possible explanation for BP changes may be that a larger number of motor units were activated with 10-15RM loads which stimulated a greater decrease in plasma volume and subsequently, a greater drop in cardiac output and systolic volume. Additionally, when a quick analysis of the number of repetitions was performed, GrpH performed 60 repetitions during the exercise session while GrpM and GrpL performed 120 and 180 repetitions respectively. Previous research that observed similar reductions in BP after RT, had their participants performed be-

tween 65-80 repetitions (Figueiredo et al., 2015) but these results were not seen when repetitions or load intensities were insufficient to trigger positive BP responses (Niemelä et al., 2008). It may be that moderate load intensities need to be performed for higher number of repetitions, culminating in higher training volumes, to elicit longer hypotension after RT exercises in men. It may also be important to consider the position adopted for testing BP after the exercise session

### HRV Changes

HRV is an indicator of the synchronization between the cardiovascular system and the autonomous nervous system. Current evidence suggests that increased HRV is important for reducing risks in both healthy and patients with heart-related problems. Of the two HRV parameters, LFnu levels and how long the levels are prolonged are indicators about the sympathetic nervous system, while HFnu levels give similar information regarding the parasympathetic nervous system. The results from this study indicated that HFnu was reduced for GrpM and GrpL (up to 90 min) longer than that for GrpH (up to 75 min), while the LFnu increased for GrpM and GrpH (up to 75 min) longer than GrpL (up to 60 min) without much difference between LFnu and HFnu, and both the sympathetic and parasympathetic systems activation lasted much longer when moderate to higher loads were used. These findings are consistent with those of Rezk et al., (2006) who recruited 17 young healthy participants to perform RT with either 40% or 80% of maximum repetition and found an increase in HFnu and a decrease in LFnu after an exercise session for both groups. One other study (Heffernan et al., 2006) had depressed HFnu for 30 min post-exercise using an RT program with three sets of 10 repetitions of eight different exercises. As with BP changes, it seems higher training volumes seem to bring about better HRV reactions, and it seems possible that these results are due to the longer activation of baroreceptors after performing RT with moderate to lighter loads.

### Modification of RT Programme Variables

The results of this study have practical applications related to the modification of training variables for RT. Based on the results from this previous studies, moderate loads of 10-15RM with repetitions higher than 80 in total seem to elicit better BP and HRV responses. A program that utilized 240 repetitions (Heffernan et al., 2006) was not detrimental to HFnu responses. Moreover, this study supports the use of 10-15RM loads as they seemed to increase sympathetic activation along with reducing parasympathetic activity, which reduces the risk for both healthy individuals and patients with cardiovascular disease (Figueiredo et al., 2016) even with only one session of RT training. However, previous research did not establish clearly the isolated effect of load intensities on cardiac autonomic modulation and BP (Heffernan et al., 2006; Rezk et al., 2006; Figueiredo et al., 2015). The results of this study could help outline the effectiveness of load intensities on BP and HRV, and help individuals looking for rapid parasympathetic reactivation, and those concerned with identifying and employing specific

load intensities to maximize the effect of the acute training adaptations on BP and HRV for healthy, physically active men. Future research on the influence of RT on BP and HRV should consider examining other training variables such as rest intervals between sets, number of sets, exercise order, exercise tempo. The number of sets and rest intervals between sets are important as the higher or lower number of the sets or rest interval can affect the results. Moreover, the influence of the exercise tempo is important since during this study the first repetitions were executed at higher tempo (velocity) and when muscle fatigue occurred there was a significant reduction in repetitions velocity until the exercise was over. This may limit methodological variables of this experiment, since it may affect the muscle fatigue, number of repetitions and type of strength training.

### CONCLUSIONS

The findings of this study suggest strength and conditioning professionals to prescribe RT exercises with the load of 10RM or 15RM when the goal is to reduce BP and to improve HRV effects, and these loads accumulating to at least 80 repetitions can be considered for those who are at the risk of cardiovascular diseases. More evidence is needed to assess if these results change with different rest intervals, exercise order and exercise tempo utilised during a training session.

### REFERENCES

- American College of Sports Medicine (Ed.). (2013). ACSM's health-related physical fitness assessment manual. Lippincott Williams & Wilkins.
- Amani, A. R., Sadeghi, H., & Afsharnezhad, T. (2018). Interval training with blood flow restriction on aerobic performance among young soccer players at transition phase. *Montenegrin Journal of Sports Science and Medicine*, 7(2), 5. doi: 10.26773/mjssm.180901
- Chen, J. L., Yeh, D. P., Lee, J. P., Chen, C. Y., Huang, C. Y., Lee, S. D.,... & Kuo, C. H. (2011). Parasympathetic nervous activity mirrors recovery status in weightlifting performance after training. *The Journal of Strength & Conditioning Research*, 25(6), 1546-1552. doi: 10.1519/JSC.0b013e3181da7858
- Collier, S. R., Kanaley, J. A., Carhart Jr, R., Frechette, V., Tobin, M. M., Bennett, N.,... & Fernhall, B. (2009). Cardiac autonomic function and baroreflex changes following 4 weeks of resistance versus aerobic training in individuals with pre-hypertension. *Acta physiologica*, 195(3), 339-348. doi: 10.1111/j.1748-1716.2008.01897.x
- Dekker, J. M., Crow, R. S., Folsom, A. R., Hannan, P. J., Liao, D., Swenne, C. A., & Schouten, E. G. (2000). Low heart rate variability in a 2-minute rhythm strip predicts risk of coronary heart disease and mortality from several causes: the ARIC Study. *Circulation*, 102(11), 1239-1244. doi: 10.1161/01.cir.102.11.1239
- Figueiredo, T., Rhea, M. R., Peterson, M., Miranda, H., Bentes, C. M., dos Reis, V. M., & Simao, R. (2015). Influence of number of sets on blood pressure and heart rate variability after a strength training session. *Journal*

- of Strength and Conditioning Research, 29(6), 1556-1563. doi: 10.1519/JSC.0000000000000774
- Figueiredo, T., Willardson, J. M., Miranda, H., Bentes, C. M., Reis, V. M., & Simao, R. (2015). Influence of Load Intensity on Postexercise Hypotension and Heart Rate Variability after a Strength Training Session. *Journal of Strength and Conditioning Research*, 29(10), 2941-2948. doi: 10.1519/JSC.0000000000000954
- Figueiredo, T., Willardson, J. M., Miranda, H., Bentes, C. M., Machado Reis, V., Freitas de Salles, B., & Simão, R. (2016). Influence of rest interval length between sets on blood pressure and heart rate variability after a strength training session performed by prehypertensive men. *Journal of strength and conditioning research*, 30(7), 1813-1824. doi: 10.1519/JSC.0000000000001302
- Gregoire, J., Tuck, S., Hughson, R. L., & Yamamoto, Y. (1996). Heart rate variability at rest and exercise: influence of age, gender, and physical training. *Canadian Journal of Applied Physiology*, 21(6), 455-470. doi: 10.1139/h96-040
- Hagerman, F. C., Walsh, S. J., Staron, R. S., Hikida, R. S., Gilders, R. M., Murray, T. F, Ragg, K. E. (2000). Effects of high-intensity resistance training on untrained older men. I. Strength, cardiovascular, and metabolic responses. *The journals of gerontology series A: Biological Sciences and medical sciences*, 55(7), B336-B346. doi: 10.1093/gerona/55.7.b336
- Heffernan, K. S., Fahs, C. A., Shinsako, K. K., Jae, S. Y., & Fernhall, B. (2007). Heart rate recovery and heart rate complexity following resistance exercise training and detraining in young men. *The American Journal of Physiology-Heart and Circulatory Physiology* 293(5), H3180-3186. doi: 10.1152/ajpheart.00648.2007
- Heffernan, K. S., Kelly, E. E., Collier, S. R., & Fernhall, B. (2006). Cardiac autonomic modulation during recovery from acute endurance versus resistance exercise. *European Journal of Cardiovascular Prevention & Rehabilitation*, 13(1), 80-86. doi: 10.1152/ajpheart.00648.2006
- Kors, J. A., Swenne, C. A., & Greiser, K. H. (2007). Cardiovascular disease, risk factors, and heart rate variability in the general population. *Journal of electrocardiology*, 40(1), S19-S21. doi: 10.1186/1471-2261-5-33
- MacDonald, J. R. (2002). Potential causes, mechanisms, and implications of post-exercise hypotension. *Journal of human hypertension*, 16(4), 225-236. doi: 10.1038/sj.jhh.1001377
- Niemela, T. H., Kiviniemi, A. M., Hautala, A. J., Salmi, J. A., Linnamo, V., & Tulppo, M. P. (2008). Recovery pattern of baroreflex sensitivity after exercise. *Medicine and science in sports and exercise*, 40(5), 864. doi: 10.1249/MSS.0b013e3181666f08
- Neto, G. R., Sousa, M. S., Costa, P. B., Salles, B. F., Novaes, G. S., & Novaes, J. S. (2015). Hypotensive effects of resistance exercises with blood flow restriction. *The Journal of Strength & Conditioning Research*, 29(4), 1064-1070 doi: 10.1519/R-164
- Nekooei, P., Tengku-Fadilah, T. K., Amri, S., Baki, R. B., Majlesi, S., & Nekouei, P. (2019). Anatomical Shoulder Movement Strength Imbalance Among Water Polo Overhead Athletes. *International Journal of Kinesiology and Sports Science*, 7(2), 15-20. doi: http://dx.doi.org/10.7575/aiac.ijkss.v.7n.2p.15
- Piras, A., Persiani, M., Damiani, N., Perazzolo, M., & Raffi, M. (2015). Peripheral heart action (PHA) training as a valid substitute to high intensity interval training to improve resting cardiovascular changes and autonomic adaptation. *European Journal of Applied Physiology* 115(4), 763-773. doi: 10.1007/s00421-014-3057-9
- Pescatello, L. S., Guidry, M. A., Blanchard, B. E., Kerr, A., Taylor, A. L., Johnson, A. N.,... Thompson, P. D. (2004). Exercise intensity alters postexercise hypotension. *Journal of hypertension*, 22(10), 1881-1888. doi: 10.1097/00004872-200410000-00009
- Rezk, C. C., Marrache, R. C., Tinucci, T., Mion, D., Jr., & Forjaz, C. L. (2006). Post-resistance exercise hypotension, hemodynamics, and heart rate variability: influence of exercise intensity. *European journal of applied physiology*. 98(1), 105-112. doi: 10.1007/s00421-006-0257-y
- Sandercock, G. R., Bromley, P. D., & Brodie, D. A. (2005). Effects of exercise on heart rate variability: inferences from meta-analysis. *Journal of Medicine and Science in Sports and Exercise*, 37(3), 433-439. doi: 10.1249/01.mss.0000155388.39002.9d
- Sztajzel, J. (2004). Heart rate variability: a noninvasive electrocardiographic method to measure the autonomic nervous system. *Swiss medical weekly*, 134, 514-522. DOI: 2004/35/smw-10321
- Tarvainen, M. P., Niskanen, J. P., Lipponen, J. A., Ranta-Aho, P. O., & Karjalainen, P. A. (2014). Kubios HRV—heart rate variability analysis software. *Computer methods and programs in biomedicine*, 113(1), 210-220. Doi: 10.1016/j.cmpb.2013.07.024
- Teixeira, L., Ritti-Dias, R. M., Tinucci, T., Júnior, D. M., & de Moraes Forjaz, C. L. (2011). Post-concurrent exercise hemodynamics and cardiac autonomic modulation. *European journal of applied physiology*, 111(9), 2069-2078. doi: 10.1007/s00421-010-1811-1
- Wanderley, F. A., Moreira, A., Sokhatska, O., Palmares, C., Moreira, P., Sandercock, G.,... & Carvalho, J. (2013). Differential responses of adiposity, inflammation and autonomic function to aerobic versus resistance training in older adults. *Experimental gerontology*, 48(3), 326-333. doi: 10.1016/j.exger.2013.01.002