UNIVERSITI PUTRA MALAYSIA

EFFECTS OF MANIPULATING RESISTANCE TRAINING VARIABLES ON POST EXERCISE BLOOD PRESSURE AND HEART RATE VARIABILITY

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By

BEHZAD ALEMI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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EFFECTS OF MANIPULATING RESISTANCE TRAINING VARIABLES ON POST EXERCISE BLOOD PRESSURE AND HEART RATE VARIABILITY

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September 2019

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The purpose of this study was to compare blood pressure (BP) and heart rate variability (HRV) responses in physical active men after resistance training (RT) with different rest interval (RI) between sets (1, 2 and 3 minutes) and 3 different number of sets (3, 5 and 7 sets) with loads of 5 repetition maximum 5RM, 10RM, and 15RM. The HRV frequency-domain analysis provided high frequency (HF) and low frequency (LF) measurements which reflects sympathetic and parasympathetic activation. BP responses were measured in systolic (SBP) and diastolic (DBP). Due to large number of study variables we conducted two studies. Eighty-one men (21.6 ± 1.1yr; body mass: 74.1 ± 8.1kg; height: 175.3 ±7.1cm) who performed moderate to vigorous activities for a minimum of 30mins a day on at least five days a week participated in this study. After determination of 5RM loads for bent-over row, bench press, dead-lift and squats, participants were divided into nine groups to perform different RT protocol in each group. Each group received different mixture of loads (5RM, 10RM or 15RM), Sets (3 Sets, 5 Sets or 7 Sets) and Rest Interval (1-min, 2-min or 3-min) for each exercise. All experimental sessions were performed in the following exercise order: squat, bench press, barbell bent-over row followed by deadlift. Before and for two hours after each session, BP and HRV were measured. The results of the first study demonstrated low, moderate and high loads intensities (5RM, 10RM and 15RM) decreased SBP up until 120 min post-exercise. However, the DBP value remained low up until 105 min in 5RM and 15RM loads. Low frequency value was increased in 5RM, 10RM and 15RM up until 75, 90 and 60 min post exercise. The LF and HF values for each RIs between sets were not significantly differed among load intensities after RT session. In the second study results demonstrated low, moderate and high loads intensities (5RM, 10RM and 15RM) decreased SBP up until 75, 90 and 120 min post-exercise respectively. However, the DBP value remained low up until 90 min for 10RM and 15RM loads and low DBP

value up until 45 min for 5RM load. Low frequency value was increased in 3, 5 and 7 sets up until 90, 105 and 120 min post-exercise respectively. High Frequency value was decreased in 3, 5 and 7 sets up until 90, 75 and 75 min post exercise respectively. The findings of this study showed a significant post-exercise BP and HRV changes after RT in physical active men. The extent of the cardiac response was related to extended number of sets, rest intervals between sets and load intensities performed during training. Higher sets with a heavier load caused a greater response in BP and HRV. Thus, strength and protocol experts may prescribe higher number of exercise, longer rest intervals between sets and exercises with higher loads when the goal is to reduce BP after RT sessions as well as to minimise cardiac stress.
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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

KESAN DARIPADA MANIPULASI PEMBOLEH UBAH LATIHAN KEKUATAN ATAS TEKANAN DARAH DAN KEBOLEHUBAHAN KADAR JANTUNG SELEPAS SENAMAN

Oleh

BEHZAD ALEMI

September 2019

Pengerusi : Kok Lian Yee, PhD
Fakulti : Pengajian Pendidikan

Tujuan kajian ini adalah untuk membandingkan tindak balas tekanan darah (BP) dan kebolehubahan kadar denyutan jantung (HRV) di kalangan lelaki yang aktif dalam activiti fizikal selepas latihan rintangan (RT) dengan selang masa yang berlainan antara set (1, 2 dan 3 minit) dan 3 bilangan set yang berbeza (3, 5 dan 7 set) dengan 5 pengulangan maksimum iaitu 5RM, 10RM, dan 15RM. Tindak balas HRV diukur dalam frekuensi tinggi (HF) dan frekuensi rendah (LF). Tindak balas BP diukur dalam systolic (SBP) dan diastolic (DBP). Kami menjalankan dua kajian kerana terdapat banyak pembolehubah dalam kajian ini,. Lapan puluh satu lelaki (21.6 ± 1.1yr; jisim badan: 74.1 ± 8.1kg; ketinggian: 175.3 ± 7.1cm) yang melakukan aktiviti yang sederhana hingga lasak sekurang-kurangnya 30 minit sehari dalam masa sekurang-kurangnya lima hari seminggu telah menyertai kajian ini. Selepas penentuan beban 5RM untuk bent-over row, bench press, dead-lift dan squats, peserta- peserta dibahagikan kepada tiga kumpulan untuk melaksanakan satu sesi RT. Setiap kumpulan menerima beban yang berbeza (5RM, 10RM atau 15RM), Set (3 Set, 5 Set atau 7 Set), interval rehat (1-min, 2-min atau 3-min) untuk setiap senaman. Semua sesi eksperimen dilakukan dalam urutan latihan berikut: bench press, deadlift, bent over row, diikuti oleh squats. Sebelum dan selama dua jam selepas setiap sesi, BP dan HRV diukur. Keputusan kajian pertama menunjukkan bahawa intensiti beban rendah, sederhana dan tinggi (5RM, 10RM dan 15RM) menurunkan SBP sehingga 120 minit selepas latihan. Walau bagaimanapun, nilai DBP kekal rendah sehingga 105 minit dalam beban 5RM dan 15RM. Nilai frekuensi rendah dinaikkan dalam 5RM, 10RM dan 15RM sehingga 75, 90 dan 60 minit selepas latihan. Nilai LF dan HF untuk setiap interval rehat di antara set tidak jauh berbeza antara intensiti beban selepas sesi RT. Dalam keputusan kajian kedua, ia menunjukkan bahawa intensiti beban yang rendah, sederhana dan tinggi (5RM, 10RM dan

15RM) menurunkan SBP sehingga 75, 90 dan 120 minit selepas latihan. Walau bagaimanapun, nilai DBP kekal rendah sehingga 90 minit untuk beban 10RM dan 15RM dan nilai DBP rendah sehingga 45 minit untuk beban 5RM. Nilai kekerapan rendah meningkat dalam 3, 5 dan 7 sets sehingga 90, 105 dan 120 minit selepas latihan. Nilai Frekuensi Tinggi dikurangkan dalam 3, 5 dan 7 set sehingga 90, 75 dan 75 minit selepas latihan. Penemuan kajian ini menunjukkan perubahan ketara dalam BP selepas latihan dan HRV selepas RT di kalangan lelaki yang aktif dalam activiti fizikal. Tahap tindak balas jantung adalah berkaitan dengan lanjutan bilangan set, interval rehat antara set dan intensiti beban yang dilakukan semasa latihan. Set yang lebih tinggi dengan beban yang berat menyebabkan tindak balas yang lebih besar dalam BP dan HRV. Oleh itu, pakar kekuatan dan protokol boleh menetapkan bilangan latihan yang lebih tinggi, interval rehat yang lebih lama antara set dan latihan dengan beban yang lebih tinggi jikalau matlamatnya adalah untuk mengurangkan BP selepas sesi RT dan juga untuk mengurangkan tekanan jantung.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisor Committee were as follow:

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Declaration by Members of Supervisory Committee

This is to confirm that:

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LIST OF ABBREVIATIONS

ANS	Autonomic Nervous System
ANOVA	Analysis of Variance
BP	Blood Pressure
DBP	Diastolic Blood Pressure
HRV	Heart Rate Variability
HF	High Frequency Power
LF	Low Frequency Power
LI	Load Intensity
PERT	Post-exercise Recovery Time Points
PNS	Parasympathetic Nervous System
RI	Rest Intervals
RT	Resistance Training
RM	Repetition Maximum
SBP	Systolic Blood Pressure
SNS	Sympathetic Nervous System
SPSS	Statistical Package for the Social Sciences

CHAPTER 1

INTRODUCTION

Background

The autonomic nervous system (ANS) is usually regarded as part of the motor division of the peripheral nervous system. Peripheral nervous system is responsible to control the body's involuntary internal function such as heart rate, blood pressure (BP), blood distribution, and respiration. These functions are part of the vascular system. The regulation by ANS is so quick that reaction can be observed within a few seconds through the heart rate functions and reactions in glands and smooth muscle tissues. The ANS reactions are measured via autonomic control of blood circulation and heart rate variability (Sztajzel, 2004).

Heart rate variability or irregular heartbeat behavior is evident when heart rate is observed on a beat-to-beat basis. However, HRV is disregarded when a mean value over time is calculated. The variations in HR are the result of non-linear and complex interactions between various physiological systems (Del Paso, Langewitz, Mulder, Roon, & Duschek, 2013). The usual method for monitoring changes in physiological systems is the heart rate tachogram which is a plot of a sequence of time intervals between R waves which is commonly known as beat-to-beat changes. The factors that contributed to beat-to-beat changes are efferent parasympathetic, sympathetic activation, various activities that appear in the heart's central nervous system as well as the afferent signals arising from chemosensory neurons and the mechanosensitive. Studying the frequency of afferent signals is termed frequency domain analysis and it is divided into three major categories namely high-frequency (HF) power which symbolises parasympathetic outflow, low-frequency (LF) power which indicate the combination of parasympathetic and sympathetic powers, and the ratio between low and high-frequency which signals indicates the sympathetic outflow (Camm et al., 1996). The frequency analysis of HRV provides information about ANS. As mentioned earlier, the ANS controls all the necessary functions that maintain homeostasis in the body such as heart rate, BP, vasodilation and vasoconstriction.

The ANS comprises of the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). SNS raises heart rate and vessel constriction through norepinephrine and epinephrine release while PNS stimulates reduction in HR and vasodilates the heart contractility and blood vessels through the secretion of acetylcholine (ACh). Both constriction and vasodilation have direct effect on the force per unit area exerted on the wall of largest arteries near the heart, and this is usually referred to as the BP. When BP is reduced, vagal input is inhibited, and venous, total peripheral resistance, HR, and heart contractility return are all increased. In turn, all the aforesaid physiological features play a role in raising cardiac output (Marieb & Hoehn, 2007).

After exercise BP can be influenced by SNS and PNS. Both the PNS and SNS regulate HR changes by constantly sending signals to the sinoatrial node (Marieb & Hoehn, 2007). Excitatory signals sent through the thoracic region of the spinal cord and inhibitory signals sent through the vagus nerves cause the vagal tone to be exhibit by the heart (Marieb & Mallatt, 2002). After exercise the activity of the ANS on BP is most often associated with a rise in cardiac output together with a decline in sympathetic nerve activity and peripheral resistance (Floras et al., 1989). Therefore, physical fitness can contribute to the regulation of the ANS since exercise or physical activity can affect ANS.

Physical fitness has strong association with the ANS, and this has been studied by applying frequency analysis of HRV. Physical fitness is improved by training the energy and muscle system. Energy system training is widely known as those training related to the metabolic processes, which generate energy for synthesis of ATP, whereas muscular system training is identified as training of muscle fibers to enhance their contractibility function. In other words, to improve the muscular system, muscle fibers need to be trained and muscle fiber development can be maximised through resistance training (RT). RT is a form of physical activity that is planned to develop muscular fitness by training a muscle or muscle groups against external resistance (ACSM, 2013). Many studies have examined the impact of exercise on HRV (Hallman et al., 2017; Makivić, Nikić, Willis, Education, & Parovića, 2013; Buchheit & Gindre, 2006; Buchheit, Laursen, & Ahmaidi, 2007).

Some studies point to energy system training and a few to RT as effectors of higher parasympathetic activity in athletes, which in training, may contribute to lower resting bradycardia. Previous studies (Eijsvogels, Fernandez, & Thompson, 2015; da Silva, et al., 2015) mentioned that higher parasympathetic activity measured from HRV analysis is a major factor that causes bradycardia in athletes. Based on this, it seems frequency analysis of HRV can deliver important information about the function of the sympathetic and parasympathetic nervous system during rest and activity (Xhyheri, Manfrini, Mazzolini, Pizzi, & Bugiardini, 2012) and can provide valuable information for healthy individuals and those with cardiovascular risk (Kors, et al., 2007).

A significant result of energy system training on resting parasympathetic outflow as measured through high-frequency (HF) power and post-exercise BP reduction was found in a meta-analysis with the greatest effect reported with longer interventions and younger participants (Sosner, Grémeaux, Arvisais, Herpin, & Bosquet, 2017; Boutcher, 2017; Sandercock, Bromley, & Brodie, 2005). Other studies have reported either a decrease or no change

(Jurca, Church, Morss, Jordan, & Earnest, 2004; Melanson & Freedson, 2001).

Other than HRV, both energy system and resistance training have also been linked to improved post-exercise BP. Despite the reports of improved HRV indices and post-exercise BP from both energy system and RT, energy system training has been mostly advised for the people who need to maintain chronic BP. Previous studies have confirmed better post-exercise BP response following energy system training and resistance training, yet very few have examined the effect of manipulating RT variables on BP (Cardoso Jr et al., 2010; Stone, 2014).

On the health related approach to comprehensive exercise, it has been recommended that RT be a part of training programs to reduce cardiovascular risks (Pescatello et al., 2004). In healthy participants, RT has induced improvement in vagal control of the heart and bradycardia (George et a.l. 1995) in addition to relative BP cutback with a dramatic decrease in both systolic and diastolic blood pressure (Collier et al., 2009). These improvements in turn, may increase measurement of HF power (Donnelly et al., 2009). Acute responses to RT indicated reduction in LF and HF power, and a substantial increase in LF/HF ratio after a training session (Heffernan et al., 2006; Chen et al., 2011).

Researchers have found that BP reduced and the HF component of HRV remained more depressed while LF component rises after RT by comparing the autonomic activity after exercise (Figueiredo et al., 2015; Figueiredo, Willardson, et al., 2015; Heffernan, Fahs, Shinsako, Jae, & Fernhall, 2007). However, since different researchers utilised different intensity (load), volume (number of repetitions), and rest intervals between the sets, it was not possible to establish clearly the isolated effect of RT on cardiac autonomic modulation and BP (Chen et al., 2011; Teixeira et al., 2011; Wanderley et al., 2013). All previous studies have only used one or two of the aforementioned variables in their experimental protocol, and yet, a program for optimum rest interval or number of the sets to be performed during each load of RT that can minimise cardiac modulation and blood pressure is not available.

Problem Statement

It has been stated that the postexercise blood pressure response are more evident in hypertensive than in normotensive individuals (Ruiz, R. J et al., 2011) while others belive no significant difference in the postexercise response between hypertensive and normotensive subjects (de Brito et al., 2019). However, at present, few studies have engaged physically active normotensive subjects in the research to measure cardiovascular events. Cardiovascular events are the main cause of death worldwide and even apparently healthy individuals specifically men may have high cardiovascular risk (Veronese et al., 2016).

In general men are at greater risk for cardiovascular than women (Coelho et al., 2017). Previous studies used the 24-hour ambulatory blood pressure monitoring and the results proved that blood pressure is higher in men than in women at similar ages (Schmidl, D et al., 2015; Coelho et al., 2017). Even though the mechanisms causing the gender differences in blood pressure are not clear, there is an evidence that testosterone, play a major role in gender related differences in blood pressure regulation. For instance, studies using ambulatory blood pressure techniques in children shown that blood pressure increases in both boys and girls. Although, after the puberty, boys have higher blood pressure than girls (Barsha et al., 2016). Furthermore, SNS activity which varies between male and female subjects can cause the changes in blood pressure in men and women subjects. Changes in blood pressure is mediated by the reduction vasoconstrictor responsiveness in those with high sympathetic activity (Joyner et al., 2016).

Previous research has revealed that, energy system training improved the indices of HRV and induces post-exercise BP reduction among male and female populations of various age groups (Carter, Banister, & Blaber, 2003; Okazaki et al., 2005; Sloan et al., 2009; Tulppo et al., 2003). Previous studies on HRV and BP changes during energy system training reported that training stimulated resting bradycardia causing lower BP accompanied by increased cardiac vagal modulation in healthy individuals (Carter, Banister, & Blaber, 2003). The changes in HRV to training were positive with longer duration of training and previous level of activity (Sandercock, Bromley, & Brodie 2005).

However, advantages resulting from the energy system training are dependent on a mandatory volume of training being executed at a relatively high intensity. This condition makes it challenging for many trainees to continue their training long enough in each exercise session to accomplish the desired level. In order to decrease the time dedicated to long and tough training and allowing high enough volume of training to be performed, many exercises chose RT (Ratamess et al., 2007).

The crucial component to RT adaptations and subsequent training responses is the design of the program (Kraemer & Ratamess, 2004). Achieving training objectives during RT programs can be attained by controlling several variables such as rest period or intervals, sets, intensity, exercise order, repetition, volume, repletion velocity and muscle action. Rest interval periods affect the removal mechanism of metabolic by-products during muscle contraction and play an important role for the reduction of muscle fatigue. Thus, the length of the rest interval can affect cardiovascular responses to RT (Simão, Farinatti, Polito, Viveiros, & Fleck, 2007) and should be considered as one of the key variables that need to be thoroughly examined.

Rest intervals (RI) required after exercise and between sets can affect hormonal (Maresh & Fry, 1991) and cardiovascular (Häkkukinen, Komi, & Alen, 1985) responses to an acute session of RT as well as training adaptations, and the performance of subsequent sets (Kraemer 1997). It has been reported that RT performance may be influenced differently with short (1 min) or long (3 min) RI (Kraemer 1997). It has also been suggested that RIs should range from 30s up until three minutes depending on the objective of the exercise or the training intensity (de Salles et al., 2009; Kraemer et al., 2002) data is unclear which rest interval can optimise HRV and BP changes to minimise cardiac autonomic modulation and BP after RT.

The next variable that must be considered is the number of sets. A set has been defined as a specific number of repetitions completed as a group without resting (ACSM, 2013). Previous studies have demonstrated great variance in the magnitude of BP changes, and also the duration those changes are maintained. Furthermore, the mechanisms underlying the cardiovascular responses after different sets of RT have hardly been examined. Current research on the probable adaptations of BP to RT suggests that changes in BP may be related to a decrease in plasma volume and hence lower venous return (Floras et al., 1989). To recompensate for this outcome, a compensatory vasoconstriction associated to baroreflex with an escalation in peripheral sympathetic activity and the vascular resistance could occur. There is some evidence suggesting that RTs can decreases the compliance and raise the stiffness of the carotid artery (Floras et al., 1989; Gritti et al., 2013).

Few studies have compared different sets of exercise and their findings are contradictory (Figueiredo et al., 2015; Polito & Farinatti, 2009), with the number of sets varying from 1 - 8 depending on intensity of the exercise. Until now, only two studies have investigated the responses of BP and HRV associated with RT variables (Figueiredo et al., 2013; Rezk et al., 2006). In RT the rest length between each set, the number of sets, and sequence of exercise have a major impact on the metabolic and mechanical responses of the vasculature. These variables also influence the response mechanisms of cardiovascular control that in turn, can affect baroreceptors (Piras, Persiani, Damiani, Perazzolo, & Raffi, 2015). Studying the outcome of the RI between each set and the number of sets on HRV and BP has often been neglected by previous researchers (Figueiredo et al., 2013; Willardson, et al., 2015; Kingsley, & Figueroa, 2016). Other than RI, it is likely that different intensities of RT stimulate different responses in cardiac autonomic modulation. Additionally, training volume influences both the duration and magnitude of HRV and BP response. All these variables need to be examined simultaneously to obtain a comprehensive explanation of their influence on HRV and BP adaptation from RT.

The previous paragraph suggested that the examination of the effect of manipulating RT variables such as RI between sets, and the number of sets to be performed during each load intensity of RT appears to be inadequate. This includes acute adaptations of HRV and BP to RT training variables. It would be logical to examine acute responses of HRV and BP to RT before conducting longer duration studies to examine chronic adaptations. Although chronic adaptations may help prevent diseases and improve overall health, it is still necessary to observe acute responses to decide if further examination over a longer training period.

This study attempted to determine which combination of different RI, load intensities (LI) and sets are most efficient for enhancing acute responses in BP reduction and HRV during RT. Based on the data collected a model to suggest the cause-and-effect relationship between the parameters and the performance measures was proposed. Furthermore, the suggested model was used to search the factor space for best trade-offs to achieve the goals that have been set for optimisation purpose.

Research Objectives

The main objective of this study was to determine the optimal combination of RT variables involving rest intervals between RT, number of sets performed, rest after RT, and LI that can achieve adequate and appropriate changes in HRV and BP to support RT as a training mode to improve cardiovascular functions. The main objective encompasses three independent variables (IV) with multiple levels for each IV. Therefore, the main objective was divided into two sub-categories that were achieved via two studies.

<u>Study 1 Research Objectives</u>

The objective of the first study was to determine the optimal rest intervals to minimise the BP and parasympathetic changes and maximise the sympathetic activity for different RT load intensities on physically active men. The specific objective of this study was to determine the effect of low (50-60% of repetition maximum or 15RM), moderate (65-80% of repetition maximum or 10RM) and high (85-90% of repetition maximum or 5RM) loads and rest intervals of 1, 2 or 3 min on changes in BP and HRV immediately after RT and at different post-exercise recovery time points (PERT) up to 120 min.

<u>Study 2 Research Objectives</u>

After identifying the optimal rest intervals for each load, the main objective of the second study was to determine the appropriate number of sets for each load, to minimise the BP and parasympathetic changes and maximise the sympathetic activity on physically active men. The specific objective of this study was to determine the effect of three, five and seven sets of RT and low (5RM), moderate (10RM) and high (15RM) loads on changes in BP and HRV immediately after RT, and at different PERT.

Research Questions and Hypotheses

The research objectives stated in the previous section will be addressed according to the following questions. Each question will be statistically addressed via the stated hypotheses.

The main research question asks which combination of rest intervals between sets, amount of rest after exercise, number of sets performed, and load intensity lifted would achieve optimum changes in BP and HRV after RT. This main question was examined via a number of secondary questions listed after this.

Study 1 Research Questions and Hypotheses

This study has two independent variables or IVs (LI and RIs between sets) that are examined for changes in two dependant variables or DVs which are BP and HRV. Making this more complex would be that the DVs were examined over eight different time point over 120 min (post-exercise at Pre, 15, 30, 45, 60, 75, 90, 105, 120 min). In other word, this study has three levels of RI and LI and nine levels on PERT. Therefore, seven questions were posed for each DV namely HRV (LF and HF power), BP (SBP and DBP) as set out below. The last question was posed to determine the optimum condition for LI and RI to achieve the best BP and HRV. For statistical illustration purpose a letter was given to each independent variable as A = LI, B = RI and C = PERT, as previously utilised in section before this.

HRV powers

Q1: Does load intensity (3 levels) affect HRV?
Ho1: There is no significant statistical mean difference in HRV after RT exercise using different load intensities.

$$\mu_{A1} = \mu_{A2} = \mu_{A3}$$

Q2: Does rest intervals (3 levels) affect HRV?
Ho2: There is no significant statistical mean difference in HRV after RT exercise using different rest intervals.

$$\mu_{B1} = \mu_{B2} = \mu_{B3}$$

Q3: Does PERT affect HRV?

Ho3: There is no significant statistical mean difference between PERT after RT in HRV.

$\mu_{C1} = \mu_{C2} = \mu_{C3} = \mu_{C4} = \mu_{C5} = \mu_{C6} = \mu_{C7} = \mu_{C8} = \mu_{C9}$

Q4: Does the influence of load intensity on HRV depend on PERT?

Ho4: There is no significant statistical interaction exist between load intensity and PERT after RT in HRV changes.

$\mu_{A1C1} = \mu_{A2C1} = \mu_{A3C1} = \mu_{A1C2} = \mu_{A2C2} = \mu_{A3C2} = \ldots = \mu_{A3C9}$

Q5: Does the influence of rest intervals on HRV depend on PERT?

Ho5: There is no significant statistical interaction exist between rest intervals and PERT after RT in HRV changes.

$\mu_{B1C1} = \mu_{B2C1} = \mu_{B3C1} = \mu_{B1C2} = \mu_{B2C2} = \mu_{B3C2} = \ldots = \mu_{B3C9}$

Q6: Does the influence of load intensity on HRV depend on rest intervals?

H6: There is no significant statistical interaction exist between rest intervals and load intensity after RT in HRV changes.

$\mu_{A1B1} = \mu_{A2B1} = \mu_{A3B1} = \mu_{A1B2} = \mu_{A2B2} = \mu_{A3B2} = \ldots = \mu_{A3B3}$

Q7: Does the influence of load intensity and rest intervals on HRV is different across the PERT?

Ho7: There is no significant statistical 3-way interaction between load intensity, rest intervals and PERT after RT in HRV changes.

$\mu_{A1B1\,C1} = \mu_{A2B1C1} = \mu_{A3B1C1} = \mu_{A1B2C1} = \mu_{A3B2C1} = \ldots = \mu_{A3B3C9}$

<u>Blood pressure</u>

Q8: Does load intensity (3 levels) affect BP?

Ho8: There is no significant statistical mean difference in BP after RT exercise using different load intensities

$\mu_{A1} = \mu_{A2} = \mu_{A3}$

Q9: Does rest intervals (3 levels) affect BP?

Ho9: There is no significant statistical mean difference in BP after RT exercise using different rest intervals

$\mu_{B1} = \mu_{B2} = \mu_{B3}$

Q10: Does PERT affect BP?

Ho10: There is no significant statistical mean difference between PERT after RT in BP.

$\mu_{C1} = \mu_{C2} = \mu_{C3} = \mu_{C4} = \mu_{C5} = \mu_{C6} = \mu_{C7} = \mu_{C8} = \mu_{C9}$

Q11: Does the influence of load intensity on BP depend on PERT?

Ho11: There is no significant statistical interaction exist between load intensity and PERT after RT in BP changes.

$\mu_{A1C1} = \mu_{A2C1} = \mu_{A3C1} = \mu_{A1C2} = \mu_{A2C2} = \mu_{A3C2} = \ldots = \mu_{A3C9}$

Q12: Does the influence of rest intervals on BP depend on PERT?

Ho12: There is no significant statistical interaction exist between rest intervals and PERT after RT in BP changes.

$\mu_{B1C1} = \mu_{B2C1} = \mu_{B3C1} = \mu_{B1C2} = \mu_{B2C2} = \mu_{B3C2} = \ldots = \mu_{B3C9}$

Q13: Does the influence of load intensity on BP depend on rest intervals?

Ho13: There is no significant statistical interaction exist between rest intervals and load intensity after RT in BP changes.

$\mu_{A1B1} = \mu_{A2B1} = \mu_{A3B1} = \mu_{A1B2} = \mu_{A2B2} = \mu_{A3B2} = \ldots = \mu_{A3B3}$

Q14: Does the influence of load intensity and rest intervals on BP is different across the PERT?

Ho14: There is no significant statistical 3-way interaction between load intensity, rest intervals and PERT after RT in BP changes.

$\mu_{A1B1C1} = \mu_{A2B1C1} = \mu_{A3B1C1} = \mu_{A1B2C1} = \mu_{A2B2C1} = \ldots = \mu_{A3B3C9}$

Optimum condition for study 1

Q15: What is the optimum rest interval for each load intensity to achieve best BP and HRV responses?

Study 2 Research Questions and Hypotheses

This study has two independent variables or IVs (load intensity and numbers of sets) that are examined for changes in two dependant variables or DVs which are BP and HRV. Making this more complex would be that the DVs were examined over eight different time point over 120 min (post-exercise at Pre,15, 30, 45, 60, 75, 90, 105, 120 min). In other word, this study has three levels of RI and sets and nine levels on PERT. Therefore, seven questions were posed for each DV namely LF, HF, SBP, and DBP as set out below. The last question was posed to determine the optimum condition for LI and sets to achieve the best BP and HRV. For statistical illustration purpose a letter was given to each independent variable as A = LI, B = Sets and C = PRT.

HRV power

Q16: Does load intensity (3 levels) affect HRV?
Ho16: There is no significant statistical mean difference in HRV after RT exercise using different load intensities.

$\mu_{A1} = \mu_{A2} = \mu_{A3}$

Q17: Does sets (3 levels) affect HRV?
Ho17: There is no significant statistical mean difference in HRV after RT exercise using different sets.

$\mu_{B1} = \mu_{B2} = \mu_{B3}$

Q18: Does PERT affect HRV?
Ho18: There is no significant statistical mean difference between PERT after RT in HRV.

$\mu_{C1} = \mu_{C2} = \mu_{C3} = \mu_{C4} = \mu_{C5} = \mu_{C6} = \mu_{C7} = \mu_{C8} = \mu_{C9}$

Q19: Does the influence of load intensity on HRV depend on PERT?
Ho19: There is no significant statistical interaction exist between load intensity and PERT after RT in HRV changes.

$\mu_{A1C1} = \mu_{A2C1} = \mu_{A3C1} = \mu_{A1C2} = \mu_{A2C2} = \mu_{A3C2} = \ldots = \mu_{A3C9}$

Q20: Does the influence of sets on HRV power depend on PERT?
Ho20: There is no significant statistical interaction exist between sets and PERT after HRV changes.

$\mu_{B1C1} = \mu_{B2C1} = \mu_{B3C1} = \mu_{B1C2} = \mu_{B2C2} = \mu_{B3C2} = \ldots = \mu_{B3C9}$

Q21: Does the influence of load intensity on HRV depend on sets?
H21: There is no significant statistical interaction exist between sets and load intensity after RT in HRV changes

$\mu_{A1B1} = \mu_{A2B1} = \mu_{A3B1} = \mu_{A1B2} = \mu_{A2B2} = \mu_{A3B2} = \ldots = \mu_{A3B3}$

Q22: Does the influence of load intensity and sets on HRV is different across the PERT?
Ho22: There is no significant statistical 3-way interaction between load intensity, sets and PERT after RT in HRV changes.

$\mu_{A1B1C1} = \mu_{A2B1C1} = \mu_{A3B1C1} = \mu_{A1B2C1} = \mu_{A2B2C1} = \ldots = \mu_{A3B3C9}$

Blood pressure

Q23: Does load intensity (3 levels) affect BP?

Ho23: There is no significant statistical mean difference in BP after RT exercise using different load intensities.

$\mu_{A1} = \mu_{A2} = \mu_{A3}$

Q24: Does sets (3 levels) affect BP?

Ho24: There is no significant statistical mean difference in BP after RT exercise using different sets.

$\mu_{B1} = \mu_{B2} = \mu_{B3}$

Q25: Does PERT affect BP?

Ho25: There is no significant statistical mean difference between PERT after RT in BP.

$\mu_{C1} = \mu_{C2} = \mu_{C3} = \mu_{C4} = \mu_{C5} = \mu_{C6} = \mu_{C7} = \mu_{C8} = \mu_{C9}$

Q26: Does the influence of load intensity on BP depend on PERT?

Ho26: There is no significant statistical interaction exist between load intensity and PERT after RT in BP changes.

$\mu_{A1C1} = \mu_{A2C1} = \mu_{A3C1} = \mu_{A1C2} = \mu_{A2C2} = \mu_{A3C2} = \ldots = \mu_{A3C9}$

Q27: Does the influence of sets on BP depend on PERT?

Ho27: There is no significant statistical interaction exist between sets and PERT after RT in SBP and DBP changes.

$\mu_{B1C1} = \mu_{B2C1} = \mu_{B3C1} = \mu_{B1C2} = \mu_{B2C2} = \mu_{B3C2} = \ldots = \mu_{B3C9}$

Q28: Does the influence of load intensity on BP depend on sets?

Ho28: There is no significant statistical interaction exist between sets and load intensity after RT in BP changes.

$\mu_{A1B1} = \mu_{A2B1} = \mu_{A3B1} = \mu_{A1B2} = \mu_{A2B2} = \mu_{A3B2} = \ldots = \mu_{A3B3}$

Q29: Does the influence of load intensity and sets on BP is different across the PERT?

Ho29: There is no significant statistical 3-way interaction between load intensity, sets and PERT after RT in BP changes.

$\mu_{A1B1C1} = \mu_{A2B1C1} = \mu_{A3B1C1} = \mu_{A1B2C1} = \mu_{A2B2C1} = \ldots = \mu_{A3B3C9}$

Optimum condition for study 2

Q30: What is the optimum number of sets to achieve best BP and HRV responses?

Significance of the Study

HRV was originated in the 1960's to assess and monitor cardiovascular events, fetal stress and recovery from surgical procedures (Collier et al., 2009). HRV was and is still used in the Russian space program to assess stress in their astronauts. HRV helped determine how an astronaut's body responded to extreme environmental changes of zero gravity and changes to autonomic cardiovascular control. In short, HRV provide a window to the efficiency of the ANS, which can be influenced by exercise and training (Donnelly et al., 2009).

In practice, it has always been a challenge to accurately measure the effects of training on the ANS. For example, establishing the load to be lifted, pushed or pulled during an exercise to optimise HRV, or selecting the number of sets and the rest intervals to help a trainee achieve optimal response during training and reduce the risk of over training is based more on a coach's experience rather than scientific data. Therefore, the examination of changes in BP and HRV according to manipulation of load intensity and rest may be useful as additional "field" indicators of whether training stress is adequate.

Reinforcing the usefulness of HRV as an indicator for determining recovery from training and workouts was a study by Morales et al., (2014) utilising judo athletes. This was reconfirmed in other studies correlating HRV and recovery from training as well as soft tissue pathology (Hellard et al., 2011) and strength with levels of the DHEA hormone (a hormone crucial for neural repair) in competitive power lifters (Steinacker, Lormes, Reissnecker, & Liu, 2004). Therefore, it seems that coaches and athletes need to utilise HRV as an indicator for over training.

The results of this study would help outline the effectiveness of RT on HRV and BP and help those individuals looking for low disturbance to homeostasis after training by allowing adequate training stimulus for rapid parasympathetic reactivation, and for those who are concerned with identifying and employing specific RT variables to maximise the effect of the acute training adaptation to HRV and BP in order to design optimal training programs which can be prescribed for healthy individuals, and also athletes.

Limitations

The delimiting factor that this research is faced was that HRV and BP were measured for 120 minutes post treatment.

Limitations are effects that cannot be controlled by the researchers. Limitations are the defects, influences or conditions that are uncontrollable by the researchers which cause the researchers to make restricted conclusions and methodology in their study. Any limitation which may affect the results of the study should be declared. Some limitations in experimental research may also mean that the findings cannot be generalised to the larger population. This is specifically correct when the definition of the population is broad, and the sample is not representing the characteristics of the whole population. In this research, the population of the experimental group has been delimited to physically active male participants aged between 18-25 years with low risk of cardiovascular disease, non-smoker, free from metabolic and cardio pulmonary diseases.

Moreover this research is an experimental research and just like any other experimental research, it is subjected to human participation and humans are exposed to error and this can somehow affect the efficiency of the results. Like in this research, absolute measurement of human performance and individuals' maximal active effort cannot be guaranteed. Therefore to minimise the aforementioned biases and for the maintenance of maximal effort while lifting high intensities of RT (which is subjective), the researcher verbally encouraged the participants to perform their best.

The next limitation arose from the point of view of researchers. Some researchers may consider using invasive methods to obtain BP and HRV measurements as they feel this has a higher level of accuracy. This study is limited to utilising non-invasive methods for measurements of BP and HRV. Although allegations are debatable, but this study used non-invasive but equipment, with well-established procedures that have been previously validated and with reliability values been reported previously (Sztajzel, 2004).

Definitions

In any research it is important to define all the variables and terms. In this research variables and terms are defined according to the title of the study, including HRV, BP, and RT. These variables are defined conceptually and operationally.

Blood pressure (BP)

The pressure of the blood in the vessels that circulates throughout the body in particular the arteries is known as BP. The BP varies depending on the volume of blood being pumped to the vessels, the elasticity of the blood vessels and the strength of the heartbeat. Arterial BP is frequently measured by using a sphygmomanometer with millimeters of mercury (mm Hg) as the manometric unit. The BP readings are indicated as a ratio of numerator equal to the BP during systole (between heart beats, when heart is relaxed) over the denominator equal to the BP during diastole (while the heart beating) (Cardoso Jr, et al., 2010). In this study, an electronic sphygmomanometer was used to measure BP (the pressure applied by the blood on the wall of arteries) and the manometric unit used is millimeter of mercury (mm Hg) (Keese, Farinatti, Pescatello, & Monteiro, 2011).

Heart Rate Variability (HRV):

Is the physiological rhythms imbedded in the beat-to- beat heart rate signal or the physiological occurrence of variation in the time interval between heartbeats. It is identified by the variation in the beat-to-beat interval (Algra, Tijssen, Roelandt, Pool, & Lubsen, 1991).In this study HRV was measured via frequency-domain using Polar, Team, USA. (Makivić[1], et al., 2013) Common frequency domain measures include high frequency (HF) and Low frequency (LF). The HF and LF activities are typically expressed in term of "power", which uses the milliseconds squared (ms2) units. This study uses HF power and LF power to measure the HRV.

Resistance Training (RT)

Resistance training is a type of physical exercise specifying in the use of resistance to produce greater muscle contractions which builds the muscle endurance, size, tone and strength. Basically it is defined as training designed to increase the body's strength, power, and muscular endurance through RT (ACSM 2013). In this study RT was performed using free weight, barbells and weight plates set at loads of muscle endurance (15RM), muscle hypertrophy (10RM), muscle strength (5RM) (ACSM, 2013). Moreover, the RT variables of this study defined as below:

Load intensity (LI): The weight lifted during RT session and it has reported as repetition maximum (RM).

Number of sets: A group of consecutive repetitions for each RT exercise.

Rest intervals (RT): The time spent resting between the sets of RT.

Post-exercise recovery time points (PERT): The time spent resting after RT session.

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LIST OF PUBLICATIONS

Articles:

Behzad Alemi, Kok Lian Yee, Chee Chen Soon (2020) Changes in Heart Rate Variability and Post Exercise Blood Pressure from Manipulating Load Intensities of Resistance-Training. International Journal of Kinesiology and Sports Science vol.10 / Pg. 13-19 /31.03.2020.

Behzad Alemi, & Kamalden, Y. T. F. T. EFFECT OF STRENGTH TRAINING PROGRAMS ON SHOULDER AND SCAPULAR MUSCLE AMONG ELITE.

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