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Hypotensive response after resistance exercise leading to failure and not to failure in trained men

Hamid Mohebbi[1], Abdulbaset Maroofi[1]

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Original Article

1. Department of Exercise Physiology, Faculty of Physical Education and Sport Sciences, University of Guilan, Rasht, Iran
Correspondence to: Hamid Mohebbi, Department of Exercise Physiology, Faculty of Physical Education and Sport Sciences, University of Guilan, Rasht, Iran
Email: mohebbi@guilan.ac.ir

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Abstract
Hypertension is epidemic disease which post-exercise hypotension (PEH) is useful strategies for hypertension. The aim of present study was to investigate the effects of resistance exercise leading to failure (REF) and resistance exercise not to failure (NREF) on PEH phenomenon in trained men. Eight trained men (age: 22.12±1.81 yr; height: 179±3.44 cm; weight: 73.82±4.29 kg; BMI: 23.01±0.84 Kg/m2 body fat 12.91±1.15%) by using the counter-balanced crossover design and in randomized order performed REF and NREF protocols by leg press machine and one session rested as control session. participants performed REF in 5 sets with 10 repetitions and NREF in 10 sets with 5 repetitions with the same load (10RM) and one min rest intervals between sets. Blood pressure was measured before and for 60 min post-resistance exercise protocols and control test. Based on the results of provided by repeated measures analysis of variance, blood pressure did not change significantly during the control test. But a significant decrease in the systolic, diastolic and mean blood pressure was observed after REF and NREF protocols when compared with the baseline values. However, duration and magnitude of PEH after REF was significantly higher in comparison of NREF protocol. The present study indicated that PEH was influenced by failure; because duration and magnitude of PEH were provided by REF was higher in comparison of NREF protocol. Therefore, REF can be more effective strategy to prevent prevalence of hypertension.

Keywords: Blood Pressure, Muscular Fatigue, Weight Training

Introduction
Hypertension (HT) is medical condition which affects approximately 1 billion people in worldwide; it represents serious risk factor for cardiovascular disease (CVD) and renal impairment [1]. There are several methods to control HT, such as pharmacological interventions and performing of physical exercise. Although pharmacological interventions are effective for control the HT, but the side effects and relatively high costs of antihypertensive medication have been proposed [1]. Nevertheless, physical exercise has been recommended as nonpharmacological approach for the prevention and treatment of HT [2]. Studies indicated that resistance training (chronic effect) can be appropriate method for blood pressure (BP) control in normotensive and hypertensive people [3,4]. Moreover, it has been shown that resistance exercise (RE/acute effect) can lead to post-exercise hypotension (PEH) phenomenon [5,6]. PEH considered as appropriate method for prevention prevalence

of HT [7]. The mechanisms that cause PEH are complex and multifactorial which may be mediated by decrease in sympathetic nervous system, cardiac output and vascular resistance or changes in the release of vasodilator metabolites [8]. RE is accompanied by significant metabolic production; these metabolites may temporarily reduce vascular resistance and BP [9]. Although most studies have demonstrated the occurrence of PEH induced by RE, but there is still no consensus an ideal protocol to enhance this phenomenon. Therefore, the current challenge for researchers is to determine the best prescription dose-response for RE in different populations. In this context, RE leading to failure (inability to perform the repetition through the movement's full range of motion as consequence of fatigue/ resistance exercise leading to failure (REF)) has been target of scientific interest. REF can increase the activity of motor units and lead to high mechanical stresses [10]. Greater motor units' recruitment by REF will lead to increase muscle activity [11]. However, greater vasodilator metabolites may be released from muscles and endothelial cells by increasing of muscle activity which subsequently is decrease in vascular resistance and BP [12]. As PEH in many participants due to sustained drop in peripheral vascular resistance [13]; change in the rate of accumulation of vasodilator metabolites may be affecting the PEH. Therefore, if these sequences occur in present study, REF may provide more significant PEH. Finally, because information on the effect of REF on the PEH seems to be lacking; the aim of present study was to investigate the effect of REF versus submaximal protocol (i.e. RE not to failure/ resistance exercise not to failure (NREF)) on PEH in trained men.

Method

A counter-balanced, crossover design was used to compare the effects of REF and NREF on PEH in trained men. Several variables such as load (intensity), total number of repetition (volume), type (active or passive) and duration of rest-intervals between sets, speed of movement (controlled by a metronome) and time under tension were controlled by equating their values between REF and NREF protocols to eliminate any possible effect of confounding factors. The lower body RE protocols consisted of performing 5 sets of 10 repetitions (i.e. REF protocol) or 10 sets of 5 repetitions (i.e. NREF protocol) for bilateral leg press exercise with same relatively intensity of their 10-RM and one minute rest intervals between sets. We established pilot testing to ensure that such training program designed for the REF protocol elicited sufficient fatigue and participants were unable to complete the final repetitions, while NREF protocol were able to complete all repetitions successfully. Whole body REF due to provide muscle soreness (participants were endurance trained) could be inconvenient for participants. Also determination of 10-RM test for whole body muscle will require a long time. Thus, to spend less time (to obtain full satisfaction of participants) and more precise control the training variables; we only tested the lower body muscles. Mac Donald et al. demonstrated that leg press exercise leads to PEH for 1-h [14]. Therefore, in the present study, REF and NREF were performed by bilateral leg press exercise machine.

Ten men physical education students of Faculty of Physical Education and Sports Science in University of Guilan (Rasht city) were randomly selected to participate in this study while two of the volunteers were unable to attend the established schedule for the experimental sessions. Therefore, eight men were recruited for this study. The participant size was statistically calculated by using G*power software (version 3.0.1; Heinrich "Heine" Universität, Düsseldorf, Germany) and based on values obtained in previous studies that observed post-resistance exercise hypotension in normotensive participants. We adopted statistical power of 0.80 and significance level of 0.05. Therefore, it was estimated minimum of eight participants would be appropriate for this study. The inclusion criteria were: normotensive, trained (none trained for competition), weight normal. The exclusion criteria were: substances use that could affect cardiovascular function, smoking, having any cardiovascular and osteomyoarticular problems that could affect performance during RE protocols, and systolic blood pressure (SBP) and diastolic blood pressure (DBP) higher than 139 and 89 mmHg respectively. All volunteers signed written consent and were informed about purpose, nature, possible risks, and benefits of the present study which was approved by the Ethics Committee of the Department of Exercise Physiology in University of Guilan (Rasht city). General characteristics of the studied participants are shown in Table 1.

Height was measured by using wall-stadiometer in precision of 1 mm. Weight and body composition was determined by In Body System (0.3, Korea). SBP and DBP were measured by standard mercury sphygmomanometer (ALPK, Japan). The measuring procedure of BP was in accordance with recommendation of American Heart Association [15] and was conducted by a trained researcher. mean arterial pressure (MAP) was calculated by conventional equation.

Two weeks before the first experiment the participants participated in a control testing day. In this session, their one repetition maximum (1RM) was determined after familiarizing participants with the leg press exercise machine. Then, after a least 10 min rest, the participants performed one set leg press exercise with the load that theoretically should produce 10 repetitions to failure (~85% 1RM). If the number of repetitions obtained was equal to 10, the load was defined as a 10-RM and used during the main tests. If the number of repetitions was more or less than 10, in order to determine the load leading to failure in exactly 10 repetitions participants were re-tested at different days with lower or higher loads.

Participants were performed three experimental sessions (i.e. REF, NREF, and control) in random order with at least 72-h rest interval between sessions. All experiments were conducted in temperature-controlled room (23 ± 1°C) between 10:00-12:00 am. Participants refrained for at least 48-h from intake of caffeine or alcoholic beverage and severe activity that demanded high energy before experimental sessions. In each session, participants rested in the laboratory in the seated position for 10 min in order to measure baseline BP. During this period, BP was measured every 2 min; the lowest and highest BP recorded values were removed and the remaining three were averaged to determine of baseline BP. Then, participants went to RE room, and they performed REF and NREF protocols or stayed resting in the leg press exercise machine as controls. Participants returned to the laboratory, and rested in the seated position for 1-h and BP was measured at 1, 5, 10, 15, 30, 45 and 60 minutes immediately after completion of the tests. The participants were asked to maintain their dietary and avoid physical exercise in the rest-interval between experimental sessions. REF and NREF protocols started with a general warm-up. Participants performed 5 set of 10 repetitions in the REF protocol whereas they completed 10 set of 5 repetitions in the NREF protocol. Intensity (10-RM), volume (50 total repetitions), type (passive) and duration of rest-intervals between sets (1 min), speed of movement (moderate/ i.e. 2 s concentric and 2 s eccentric), and time under tension (nearly 4 min) were the same in both protocols.

The normality of the data was tested by Kolmogorov Smirnov (K-S) test. The changes in BP values were calculated by the difference between the values measured pre and post intervention. These changes were compared by repeated measures analysis of variance. The bonferroni post hoc test was used to identify significant data points in analysis. One-way ANOVA and turkey's post hoc test were used to compare the BP between the control, REF and NREF tests. All data are presented as mean ± standard deviation (SD) and statistical significance was accepted at the $p<0.05$. Statistical analysis were performed by using the statistical Package for Social Sciences (SPSS v. 20®, Inc. Chicago, IL).

Results

The changes in the BP (SBP, DBP and MAP) from baseline values (pre-exercise) to 60 min post-exercise in all tests are shown in Figure 1. Baselines values BP of participants were similar (not identified any significant statistical difference) in all the experimental sessions. During the control test, BP (SBP, DBP and MAP) did not change significantly (p>0.05). SBP and MAP were significantly increased immediately after REF and NREF protocols in comparison of baseline values (p<0.05). This increasing was higher in the REF protocol in comparison of NREF. A significant PEH of SBP (at time points of 5 to 60), DBP (at time points of 1 to 15) and MAP (at time points of 5 to 30) were observed after REF in comparison of the baseline values (p<0.05). NREF also lead to significant (p<0.05) PEH of SBP (at time points of 5 to 45), DBP (at time points of 5 to 10), and MAP (at time points of 5 to 15). However, duration and the magnitude of PEH (SBP, DBP, and MAP) provided by REF was significantly higher when compared with NREF (p<0.05). Duration of PEH; REF versus NREF: SBP (55 min vs. 40 min), DBP (15 min vs. 5 min), and MAP (25 min vs. 15 min). Mean standard deviation magnitude of all the points which PEH has been observed; REF versus NREF: SBP (-6.04±2.84 vs. -3.75±1.98), DBP (-3.25±0.87 vs. -2±87), and MAP (-4.52±1.71 vs. -2.95±1.55).

Table 1 *General characteristics of the studied subjects*

Variable	Values
Age (yr)	22.12±1.81
Height (cm)	179±3.44
Weight (kg)	73.82±4.29
BMI (kg/m2)	23.01±0.84
Fat (%)	12.91±1.15

Values are shown as mean ± SD or numbers (%). BMI = body mass index

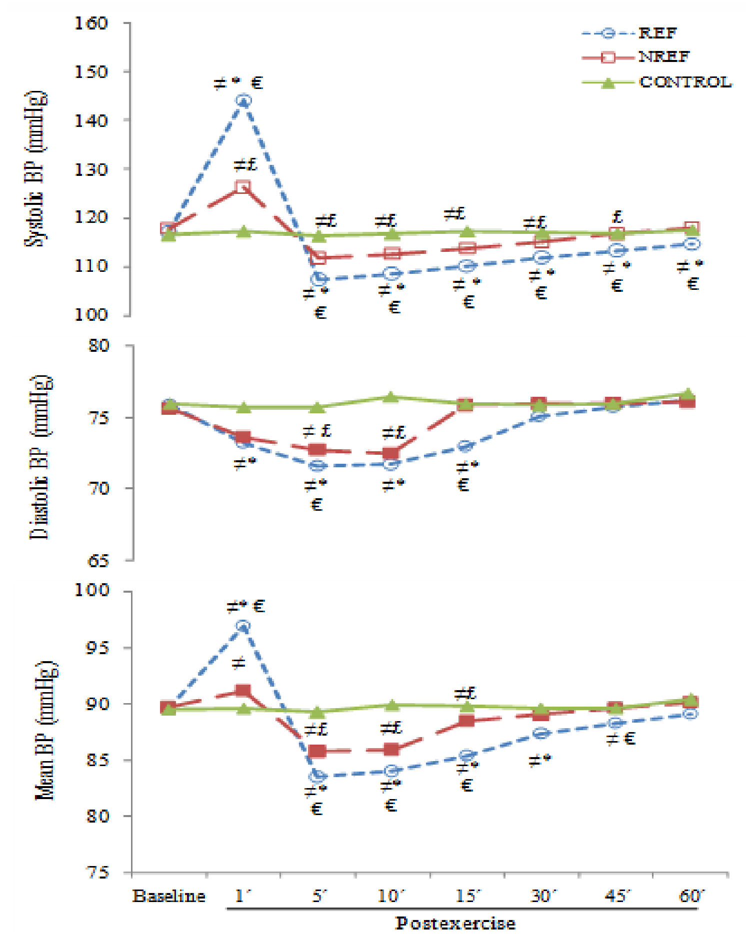

Figure 1 *SBP, DBP, and MAP measures during 60 min after REF and NREF protocols and control test*

*Significant difference in comparison of pre-exercise values for the REF ($p<0.05$); £ significant difference in comparison with pre-exercise values for NREF ($p<0.05$);≠significant difference in comparison of control test ($p<0.05$); € significant difference in comparison of NREF protocol ($p<0.05$).

Discussion

The most relevant findings of our study were that the REF and NREF resulted to PEH (SBP, DBP, and MAP) in trained men. The study indicates that the duration and magnitude of the PEH were influenced by failure. Duration and the magnitude of PEH were provided by REF was higher in comparison of NREF. As we know, this is the first study which evaluated relationship between maximal fatigue and PEH. We ensured that the PEH was induced by exercise protocols because of absence of BP modifications in the control test. Studies indicated that in the post-resistance exercise recovery period that BP may be increased [12] would be reduced [16-18] or unchanged [19] in comparison of baseline values. However, our findings confirm the obtained results in more recent studies by showing that RE significantly produce PEH [20,5,6]. The mechanisms of PEH induced by RE have not been exactly identified; this phenomenon may be related to decrease in the systolic volume possibly which was influenced by the reduction in venous return. Thus, this sequence leads to decrease in cardiac output and BP [21]. The decrease in venous return may be caused by the reduction in plasma volume [22]. In this context, following performance of RE may be blood fluid extravasation into the interstitial space and resulting to decrease in blood volume [22]. Apparently, greater motor units' recruitment by fatigue can be pulling more blood fluid into the interstitial space. This conjecture was obtained from our findings; because REF in comparison of NREF resulted to a higher PEH. Additionally, PEH may be produce due to the reduction in vascular resistance influenced by an accumulation of vasodilator metabolites in involved muscles [8]. Lactate is one of these metabolites which induce relaxation of vascular smooth muscle and thereby reduces peripheral vascular resistance [23]. In study conducted by Gorostiaga et al. lactate level produced by REF was significantly higher when compared with NREF [24]. Therefore, in this study, lactate accumulation may be one of the possible mechanisms related to higher PEH in the REF protocol.

The current study has some limitations which should be considered; the small participant size that was trained men participants is one of study's limitations in generalizing of these results to individuals with other characteristics. Moreover, PEH physiological mechanisms were not investigated. Therefore, evaluation of essential factors including the vasodilator agents, vascular sensitivity, and hemodynamic variables to explain the precision mechanisms should be considered for future studies.

Conclusion

REF and NREF protocols promote PEH in young trained men. But duration and the magnitude of PEH were higher after REF protocol. Therefore, findings of the present study revealed that muscles fatigue induced by RE that influenced the hypotensive response during the post-exercise period. If reproducible in hypertensive participants so these findings may have clinical implications.

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Contribution

Study design: HM, AM

Data collection and analysis: HM, AM

Manuscript preparation: HM, AM

Conflict of Interest

"The author declare that they have no competing interests."

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