Journal of Physical Education Research, Volume 3, Issue I, March 2016, pp.18-29
ISSN: Print-2394 4048, Online-2394 4056, Impact Factor: 0.519, IBI Factor: 4.29

THE EFFECT OF LOW-INTENSITY RESISTANCE EXERCISES WITH BLOOD FLOW RESTRICTION ON HEMODYNAMIC PARAMETERS IN YOUNG MEN

MOHAMADI SHAHRAM[1*], F. NASERKHANI[1], M. FARHOODI[1]
[1]Department of Sport Physiology, Shahrood University of Physical Education Sciences, Shahrood, IRAN.
*****Email***: shahrammohamadi131@ymail.com*

How to cite this article: Shahram, M., Naserkhani, F., & Farhoodi, M. (March, 2016). The effect of low-intensity resistance exercises with blood flow restriction on hemodynamic parameters in young men. Journal of Physical Education Research, Volume 3, Issue I, 18-29.

Received: October 24, 2015 **Accepted:** March 20, 2016

ABSTRACT

The objective of this study is to evaluate the effect of low-intensity resistance exercise with Blood Flow Restriction (BFR) on hemodynamic parameters in young men. 30 healthy young men whose ages fell within the range from 19 to 24 volunteered to participate in the study. Then, they were randomly placed in three groups of 1-low-intensity resistance exercise with BFR(LI-BFR) with an intensity of 20% 1RM, 3 sets, and 15 repetitions, 2-high-intensity resistance exercise without BFR(HIW-BFR) with an intensity of 80% 1RM, 3 sets, and 10 repetitions,3-control without exercise and BFR. Both exercise groups did squat and front leg exercises three times a week for three weeks. Hemodynamic parameters were measured one week before the first training session and 30 minutes after the last training session. Comparing groups' means, t-test and ANOVA were used (p<0.05). Data analysis showed that both exercise programs reduced hemodynamic parameters of HR, SBP, RPP and MAP compared with their pre-exercise values (p<0.05). Moreover, after three weeks of training, significant differences were observed between HR and SBP values in all groups (p<0.05). Based on the findings of the present study, hemodynamic parameters reduced 30 minutes after both low-intensity and high-intensity resistant exercises indicating positive effects of resistant exercises on hemodynamic parameters.
Keywords: *Resistance training, restriction of blood flow, blood hemodynamics*.

1. INTRODUCTION

Researchers and sports medicine experts have always been interested in cardiovascular responses resulting from exercises. Based on the results of

Correspondence: Mohamadi Shahram, M.Sc. Student, Shahrood University of Physical Education Sciences, Shahrood, IRAN, Tel: 09335087419, Email: shahrammohamadi131@ymail.com

previous studies, resistance exercises increase strengths and endurance of skeletal and cardiac muscles (Rahbar, & Ahmadiasan, 2011). However, these exercises may be accompanied by adverse responses in patients with chronic cardiovascular diseases (Afshargafari, Saedi, Zekry, & Malakyrad, 2011). Cardiovascular responses resulting from resistance exercises can be different with respect to age, gender and health status of an individual (Akdur, Yigit, Arabaci, Mine, Huyla, & Guzelsoy 2002; Okamoto, Masuhara, & Ikuta, 2008; Sagiv, Ben-Sira, & Goldhammer, 1999). Furthermore, based on their intensity levels, these exercises affect cardiac function indices differently. In this regard, Arimoto and colleagues (2005) examined cardio respiratory responses to resistance exercises and found that resistance exercises can increase Heart Rate (HR) and systolic and diastolic blood pressures during training session by exerting pressure on the cardiovascular system (Afshargafari, *et al.*, 2011). McArdel, *et al.*, (2007) showed that during a training session, a bout of resistance exercise (isometric) with 25% maximum efforts can significantly increase Blood Pressure (BP) of the examinees (McArdel, *et al.*, 2007). HR and BP are important variables to determine changes in myocardial oxygen consumption during an exercise session (Akbarynia, Ahmadi-zad, Ebrahim, Basami, Shamshaki, & Karami, 2012). Nevertheless, independent and individual evaluation of the cardiac indices and their responses to physical stresses cannot provide accurate information regarding the pressures exerted on the heart. At the same time, estimation of RPP (HR*SBP) after a physical stress like resistance exercise, can be very helpful (Afshargafari, *et al.*, 2011). RPP, an indication of cardiac workload, is highly associated with the direct measurement of coronary blood flow and myocardial oxygen consumption. RPP increases with increase of cardiac workload to provide enough blood for the cardiac muscle during an exercise session (Afshargafari, *et al.*, 2011; Akbarynia, *et al.*, 2012).

The results of previous studies showed that the level of an individual's physical fitness is related to his/her SBP, resting HR and RPP (Giddings, 2006). There is no overall consensus regarding the influence of exercise's intensity and type on cardiac performance indices. Some researchers believe that moderate to high-intensity exercises can be effective in lowering young people BP while low-intensity exercises have no impact on their BP (Fagard, 2001). According to some investigations, a reduction on SBP after high-intensity resistance exercises happens due to an increase in muscle mass (Arazi, Damirchi, Mehrabani, & Afkhami, 2012). Therefore, it seems that resistance exercises that are associated with an increase in muscle mass can improve cardiac performance indices.

Despite it has been advised to do high-intensity resistance exercises (above 80% 1RM) to prevent loss of muscle mass during health-related weight loss programs, it has been proved that these exercises are accompanied by various complications such as tissues and joints damages, swelling and reduction in central arterial compliance (Miyachi, Kawano, Sugawara, Takahashi, Hayashi, Yamazaki, Tabata, & Tanaka, 2004). This suggests that high-intensity resistance exercises are not recommended for some people, especially the elderly and cardiovascular patients. Recent research results in the fields of fitness and rehabilitation have presented new forms of resistance exercises that despite they satisfy what is expected from high-intensity exercises, they have less practical limitations. These exercises, called resistance exercises with Blood Flow Restriction (BFR), amazingly result in muscle hypertrophy and increased muscle strength in a short time and their effects are comparable with the effects obtained from high-intensity resistance exercises (Takarada, Sato, & Ishii, 2002; Takarada, Takazawa, Sato, Takebayashi, Tanaka, & Ishii, 2000). Based on the scientific evidences, a reduction in blood flow during exercise is one of the necessary compatibility requirements after resistance exercises (Yasuda, Ogasawara, Sakamaki, Ozaki, Sato, & Abe, 2011). The unique feature of resistance exercises with BFR is to perform them with a low-intensity level (20-30% 1RM) (Manini, & Clark, 2009). The results showed that even hiking with BFR can increase muscle hypertrophy and strength and helps maintain muscle mass. Research findings indicated that the amounts of muscle hypertrophy and increase of strength after resistance exercises with BFR (intensity of 20% 1RM) are similar to the amounts of muscle hypertrophy and increase of strength after high-intensity resistance exercises (intensity of 80% 1RM) without BFR (Abe, Yasuda, Midorikawa, Sato, Kearns, & Inoue, 2005; Nishimura, Masaaki, Kato, Fukuda, Sudo, & Uchida, 2010). In this method, despite only 20% of an individual’s maximum power is used, restriction of blood flow results in similar results to the results obtained from high-intensity resistance exercises. It must be noted that the exact mechanism of muscle hypertrophy after resistance exercises with BFR has not fully understood yet.

During low-intensity resistance exercises with BFR, SBP following the restriction of venous blood return done by a cuff or stretchy bands causes turbulent blood flow and increased metabolic stress and fast-twitch motor units in skeletal muscles (Manini, & Clark, 2009; Suga, Okita, & Morita, 2009). However, at the end of the exercises, blood flow and vasodilation of the area previously restricted with a cuff increase. In this regard, Takano, Morita, Iida, Asada, Kato, Uno, ... &, Nakajima, (2005) found that HR and BP are significantly higher during exercises with BFR compared with exercises without BFR. They also reported that resistance exercises with BFR reduce cardiac workload and probably stimulate vascular endothelial growth factor to response. According to a review of the literature, there are few studies regarding the effects of exercises with BFR on cardiac performance indices and the findings of these few studies are still inconsistent (Arazi, *et al.*, 2012). Accordingly, in the present study, the effects of low-intensity exercises with BFR will be compared to the effects of high-intensity exercises without BFR on cardiac performance indices.

2. METHODS AND MATERIALS

2.1 Subjects

This research is a quasi-experimental study with pretest-posttest design and a control group. The population was all male third-year paramedical students at Army University of Medical Sciences in Tehran. One month after the announcement, 40 students volunteered to participate in the experiment. After interviews and analysis of their medical records, the samples were selected based on purposive sampling method. The inclusion criteria consisted of no history of smoking, hypertension, obesity, drugs or performance-enhancing supplements use and other risk factors for cardiovascular diseases. Moreover, the participants should not do resistance exercises regularly for at least 6 months before the study started (Fleck, & Kraemer, 2004). At the first step, subjects became familiar with the project, its objectives and methodology in both written and oral forms. Then they were assured that their information would remain confidential and be coded for being used as the data. They would also be allowed to refuse if they did not want to cooperate.

2.2 Ethical Considerations

In this study, all the mentioned principles in the Declaration of Helsinki as well as the rules of medical ethics have been completely met. Accordingly, after obtaining the approval of the University Council for Research and Medical Ethics Committee, informed consent forms were signed by all subjects. Then, all the subjects answered a questionnaire containing their personal information and medical histories.

2.3 Variables

One week before starting the training program, anthropometric parameters including subjects' age, height, weight and body mass index (BMI), thigh circumference and physiological variables such comprising resting HR, SBP, DBP, and 1RM. Then, the participants were randomly placed in three training groups of 1-low-intensity resistance exercise with BFR (15 people, with an intensity of 20% 1RM), 2-high-intensity resistance exercise without BFR (12 people, with an intensity of 80% 1RM), and 3-control (13 people, without exercise and BFR). The subjects were recommended to neither take part in any other training program nor change their diets. After 3 weeks of training, all anthropometric parameters, except height, were re-measured. The formula given by Brill, Weltman, Gentili, Patrie, Fryburg, and Hanks, (2002) was used to calculate 1RM, (1RM= [the number of repetitions/30]*the used weight). Thigh circumference was measured from the center of the tight by a tape. BP was measured by a digital sphygmomanometer: the Accumed Brand, CG175f Model (made in America) and HR was measured manually for 30 seconds. RPP was calculated using the formula, RPP=HR*SBP. The Mean Arterial Pressure (MAP) was calculated through the formula given by Akbarynia, *et al.*, (2012), MAP=0.33 (SBP-DBP).

2.4 Collection of Data

Resistance training program LI-BFR included front leg and squat exercises done under the supervision of the university bodybuilding coach for three weeks (3 sessions each week). Each training session consisted of performing 15-minute warm-up exercises, 3 set of 15 repetitions of front leg and squat exercises with intensity of 20% 1RM and 15-minute cool down exercises. The subjects could rest for 30 seconds between each set. Exercise intensity was constant during the experiment. To determine the amount of BFR, power lifting stretch bands with various stretches was put on by particular subjects with different tight circumferences and phenotypes and their artery blood flows were measured by a Doppler device. The stretchiness of the used bands caused restriction of venous blood flow. Doppler ultrasound was also used to measure blood flow, BP and blood flow velocity (Wilmore, & Costill, 1994). In the first week of training, proper technique of fixing power lifting bands to the proximal end of the thigh and performing the exercises correctly were thought to the subjects. The low-intensity resistance program with BFR used in the present study was borrowed from Abe, *et al.*, (2005) and Yasuda, *et al.*, (2011) with slight variations (Kraemer, 2004; Kraemer, 2001).The resistance training program without BFR consisted 3 set of 10 repetitions of front leg and squat exercises with intensity of 80% 1RM and the subjects could rest for 30 seconds between each set. To ensure health conditions of the subjects, their BPs were measured before and immediately after each session and 24 hours afterward by a physician.

2.5 Statistical Analysis

To compare the differences before and after the experiment, *t*-test and to compare the means differences between the three groups, one-way ANOVA and Tukey test were used. The data were analyzed by SPSS software version 18 (p<0.05).

3. RESULTS

In Table 1, the mean and standard deviation of anthropometric parameters and 1RM (before and after the training) and in Table 2, the mean and standard deviation of hemodynamic variables are reported. The presented data are the data obtained from 30 participants who regularly cooperated with the researcher until the end of the experiment (5 members of the resistance group LI-BFR and 5 members of the resistance group HIW-BFR refused to continue due to severe muscle pain and injuries). Data analysis results showed significant differences between the three groups' squat 1RM (p=0.03), front leg 1RM (p=0.04), resting HR (p=0.03) and SBP (p=0.03); but, no significant differences were observed between the three groups' weight (p=0.68), thigh circumference (p=0.74) and DBP (p=0.92). Results of the Tukey test indicated an insignificant difference between squat 1RM (p=0.03) and front leg 1RM (p=0.04) of the resistance group LI-BFR and control group (Table 1).

Table 1: Comparison of anthropometric parameters and muscle strengths of the subjects before and after the experiment in different groups

	LI-BFR (n=11)		**HIW-BFR (n=7)**		**Control (n=12)**	
Variables	Pre	Post	Pre	Post	pre	Post
Weight (kg)	6.54 ±75.63	6.59 ±75.90	5.45 ±71.14**	5.62 ±72.42	12.08 ±73.46	12.36 ±73.53
Tight circumference (cm)	2.97 ±54.55**	2.73 ±57.09	3.68 ±54.71**	3.93 ±55.21	3.67 ±53.77	3.68 ±53.54
Squat 1RM (kg)	5.82 ±72.52**	8.97 ±84.33*	10.82 ±65.12**	10.90 ±71.52	10.49 ±68.92	10.46 ±68.85
Front leg 1RM (kg)	2.56 ±29.00**	2.46 ±35.90*	1.25 ±28.29**	1.57 ±31.85	4.03 ±29.53	4.12 ±29.57

*Significant difference between LI-BFR group and control group after the experiment (p<0.05)
**Significant difference between groups before and after the experiment (p<0.05)

After the experiment (3 weeks of training), regarding HR, no significant difference was observed between the exercise group LI-BFR and control group (p=0.16); however, in this regard, the difference between the exercise group HIW-BFR and control group was significant (p=0.04). Concerning SBP, significant differences was observed between the exercise group LI-BFR and HIW-BFR (p=0.04) and between HIW-BFR and control group (p=0.03); but, no significant difference was detected between the exercise group LI-BFR and control group (p=1). One-way ANOVA results showed no significant differences in DBP between the examined groups after three weeks of training (p=0.92) (Table 2). According to Table 2, after the experiment, RPP and MPA were significantly reduced in both resistance groups compared to pre-exercise period while both variables significantly increased in the control group after three weeks of experiment. At the end of the experiment, no significant difference was identified between RPP and MPA values in the studied groups.

Table 2: Comparison of hemodynamic parameters of the subjects before and after the experiment in different groups

	LI-BFR (n=11)		HIW-BFR (n=7)		Control (n=12)	
Variables	Pre	Post	Pre	Post	Pre	Post
SBP	126.82	126.36†	125.86**	118.29*	122.92	126.38
(mm.Hg)	±7.06	±7.51	±4.98	±4.23	±8.36	±10.11
HR	83.09**	78.55	81.43	82.14*	70.69	72.23
(bmp)	±8.47	±6.41	±10.23	±8.21	±9.62	±9.49
RPP	10561.64**	9943.64	10250.43**	9548.43	8669.54**	9110.85
(bpm.mmHg)	±1419.31	±1196.16	±1371.20	±976.47	±1189.94	±1309.07
MPA	92.71**	91.16	91.30	88.14	89.27**	90.77
(mm.Hg)	±5.35	±5.02	±8.34	±5.30	±5.69	±5.14

†Significant difference between LI-BFR group and HIW-BFR group after the experiment (p<0.05)
**Significant difference between groups before and after the experiment (p<0.05)
*Significant difference between HIW-BFR group and control group after the experiment (p<0.05)

4. DISCUSSION

The results of this study indicated that HR, SBP, MPA and RPP decreased after three weeks of training and 30 minutes after the last training session of resistance exercises with BFR. At the end of the experiment, significant differences were observed between HR and SBP variations in all examined groups; but no significant difference was observed between MPA and RPP variations in response to BFR resistance and without BFR resistance trainings. These findings are consistent with other studies done by Lomuto, Chevalier, Jamon, Brassine, and Borne (2009), Overend, Versteegh, Thompson, Birmingham, and Vandervoort (2000), Okamoto, Masuhara, and Ikuta, (2006), Huggett, Elliott, Overend, and Vandervoort, (2004) and Suga, Okita, and Morita, (2009), and Sowmya, Maruthy, and Gupta (2010).

According to this investigation, resting HR significantly decreased after the training sessions in the resistance group LI-BFR. After-training HR differences was significant in the HIW-BFR resistance group compared to the control group; but the difference between the two resistance groups was not significant. Resting HR decrease is one of the positive consequences of exercising. HR decrease occurs by mechanisms that have not been fully understood yet. However, there is a possibility that exercises stimulating parasympathetic nervous system can reduce sympathetic nervous activity (Wilmore, & Costill, 1994). Significant decrease in HR 30 minutes after the end of resistance exercises with BFR indicates that BFR can compensate for the low-intensity of those exercises. However, as a review of the literature suggests, the impact of resistance exercises with BFR on automatic nervous system activities has not been studied yet. But it is possible that blood flow increase immediately after resistance exercises with BFR and subsequent decrease in sympathetic activities are the main reason of resting HR reduction. In the present study, resting HR after high-intensity resistance exercises slightly increased compared to pre-exercise resting HR which was not statistically significant. During resistance training, change in HR, as an essential cardiac output component, may be effective in increasing the pressure exerted on the heart due to increasing sympathetic stimulation or decreasing parasympathetic effects. It seems that a 30-minute period of rest after training with 80% 1RM does not provide enough time to reverse the processes of sympathetic and parasympathetic nervous system that lead to decrease in HR.

After-exercise reduction in SBP can be due to reduced activity of the constriction sympathetic system and vascular resistance occurring after exercise (Takano, *et al.*, 2005; Faramarzi, Azmyan, & Ghasemian, 2012). A review of the literature indicates that little research has examined HR and BP after exercises with BFR. Due to the nature of exercises with BFR, hemodynamic parameters should be controlled during training sessions. In this regard, Takano, *et al.* (2005) reported that during-exercise HR and SBP increase significantly in exercises with BFR (Takano, *et al.*, 2005). In traditional resistance exercises, during-exercise HR and SBP increase as well; therefore, a similarity between resistance with BFR and traditional resistance exercises can be expected in the pattern of changes in HR and SBP. However, due to the issue of BFR, these changes may be more in exercises with BFR compared to traditional exercises. In this study, SBP significantly decreased in the without BFR resistance group compared to the with BFR resistance group 30 minutes after training. Compared to pre-experimental period, the reduction of SBP after 3 weeks of training was significantly lower in the HIW-BFR resistance group which is in line with another research conducted by Rossow, Fahs, Sherk, Seo, and Bemben, (2011). They examined the effects of a single resistance training session with BFR on after-exercise BP and found that SBP significantly decreases after high-intensity resistance exercises (Rossow, *et al.*, 2011). Therefore, it seems that to lower BP, high-intensity resistance exercises work better that low-intensity resistance exercises even with BFR. It has been reported that a reduction in hemodynamic parameters in after-resistance exercise recovery period can be attributed to reduced sympathetic nervous system activities and changes in after-activity vascular susceptibility (Lin, Wang, Wang, & Wang, 2001). Due to the nature of RPP, its reduction can be justified by decreases in sympathetic nervous system activities and BP during the recovery period. MAP, which determines the amount of blood flow in the general circulatory system, decreased significantly in both resistance groups. MAP is related to various physiological factors such as, cardiac output, blood volume, resistance to blood flow and blood viscosity (Akbarynia, *et al.*, 2012); however, its reduction in the resistance group LI-BFR cannot be attributed to the BFR factor because similar MAP reduction was observed in the resistance group HIW-BFR as well.

5. CONCLUSIONS

To conclude, it can be stated that a reduction in hemodynamic parameters 30 minutes after a training session can be indicative of positive effects of resistance exercises on these parameters. It seems that BFR can compensate for low-intensity of resistance exercises in reducing resting HR after resistance exercises with BFR while to lower BP, high-intensity resistance exercises work better that low-intensity resistance exercises even with BFR.

At the end, it must be noted that due to the limited number of studies of this kind, conducting more extensive investigations is required to accurately understand the changing mechanism of hemodynamic parameters after resistance exercises with BFR.

6. ACKNOWLEDGEMENT

We would like to express our sincere thanks towards all the students, the Department of Physical Education, Deputy of Research and all laboratory workers of the Army University of Medical Sciences in Tehran who cooperate with use to conduct the present study.

7. REFERENCES

Abe, T., Sakamaki, M., & Fujita, S. (2010). Effects of low-intensity walk training with restricted leg blood flow on muscle strength and aerobic capacity in older adults. *Journal of Geriatric Physical Therapy*, *33*(1), 34-40.

Abe, T., Yasuda, T., Midorikawa, T., Sato, Y., Kearns, C.F., & Inoue, K. (2005). Skeletal muscle size and circulating IGF-1 are increased after two weeks of twice daily "kaatsu" resistance training. *International Journal of KAATSU Training Research*, *1*, 6-12.

Afshargafari, A., Saedi, S., Zekry, R., & Malakyrad, E. A. (2011). Comparison of static and dynamic effects of resistance training on some parameters of cardiovascular function, lactate plasma and peripheral blood leukocytes of healthy women. *Journal of Medicine, 14*(1), S76-66.

Akbarynia, A., Ahmadi-zad, S., Ebrahim, KH., Basami, M., Shamshaki, A., & Karami, R.(2012). The effect of different types of muscle contraction isokinetic hemodynamic factors in men. *Journal of Modern Rehabilitation*, *7*(2), S71-61.

Akdur, H., Yigit, Z., Arabaci, O., Mine, GP., Huyla, N.G., & Guzelsoy, D.(2002). Comparison of cardiovascular responses to isometric and isotonic exercise tests in chronic atrial fibrillation. *Japanese Heart Journal, 43*(6), 621-29.

Arazi, H., Damirchi, A., Mehrabani, G., & Afkhami, M. (2012). The effect of three upper limb resistance intensity threshold and perception of pain, blood pressure and heart rate non-athletic young men. *Journal of Mashhad University of Medical Sciences, 56*(1), S54-47.

Brill, K.T., Weltman, A.L., Gentili, A., Patrie, J.T., Fryburg, D.A., & Hanks, J.B. (2002). Single and combined effects of growth hormone and testosterone administration on measures of body composition, physical performance, mood, sexual function, bone turnover, and muscle gene expression in healthy older *men. The Journal of Clinical Endocrinology & Metabolism, 87*(12), 5649-57.

Faramarzi, M., Azmyan, A., & Ghasemian, M. (2012). The effect of resistance exercise on plasma endothelin-1 and systolic and diastolic blood pressure in older women. *Research Applied Sport Management and Life Sciences, 1*, 95-104.

Fleck, S., & Kraemer, W.J. (2004). *Resistance training andexercise prescription*. In: S.J. Fleck & W.J. Kraemer (Eds). Designing resistance training programs. (p.179-181), Champaign: Human Kinetics.

Huggett, D.L., Elliott, I.D., Overend, T.J., & Vandervoort, A.A. (2004). Comparison of heart-rate and blood-pressure increases during isokinetic eccentric versus isometric exercise in older adults. *Journal of Aging and Physical Activity*, *12*(2), 157.

Kraemer, W.J. (2004). *Neuroendocrine responses to resistanceexercise*. In: S.J. Fleck, & W.J. Kraemer (Eds). Designing resistance training programs. (p.86-107), Champaign: Human Kinetics.

Kraemer, W.J., Loebel, C.C., Volek, J.S., Ratamess, N.A., Newton, R.U., Wickham, R.B., ... & Häkkinen, K. (2001). The effect of heavy resistance exercise on the circadian rhythm of salivary testosterone in men. *Europian Journal of Appllied Physiology, 84*(1-2), 13-18.

Lamotte, M., Chevalier, A., Jamon, A., Brassine, E., & Borne, V.D. (2009). Hemodynamic response of an isokinetic testing and training session. *Isokinetics and Exercise Science,17*(3), 135-143.

Lin, H.S., Wang, W., Wang, R.Y., & Wang, P.S. (2001). Stimulatory effect of lactate on testosterone production by rat Leydig cells. *Journal of Cell Biochemestory, 83*, 147-154.

Manini, T.M., & Clark, B.C. (2009). Blood flow restricted exerciseand skeletal muscle health. *Exercise and Sport Sciences Reviews, 37*(2), 78-85.

McArdel, W.D., Katch, F.I., & Katch, V.L. (2007). *Exercise physiology (energy, nutrition, and human performance). (6th ed.)*, Philadelphia: Lippincot Williams and Wilkins.

Miyachi, M., Kawano, H., Sugawara, J., Takahashi, K., Hayashi, K., Yamazaki, K., Tabata, I., & Tanaka, H. (2004). Unfavorable effects of resistance training on central arterial compliance: A randomized intervention study. *Circulation, 110*(18), 2858-2863.

Nishimura, A., Masaaki, S., Kato, K., Fukuda, A., Sudo, A., & Uchida, A. (2010). Hypoxia increases muscle hypertrophy induced by resistance training. *International Journal of Sports Physiology and Performance, 5*, 497-508.

Okamoto, T., Masuhara, M., & Ikuta, K. (2006). Cardiovascular responses induced during high-intensity eccentric and concentric isokinetic muscle contraction in healthy young adults. *Clinical Physiology and Functional Imaging, 26*(1), 39-44.

Okamoto, T., Masuhara, M., & Ikuta, K. (2008). Relationship between plasma endothelin-1 concentration and cardiovascular responses during high-intensity eccentric and concentric exercise. *Clinical Physiology and Functional Imaging, 28*(1), 43-48.

Overend, T.J., Versteegh, Th.H., Thompson, E., Birmingham, T.B., & Vandervoort, A.A. (2000). Cardiovascular stress associated with concentric and eccentric isokinetic exercise in young and olderadults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 55*(4), B177-182.

Rahbar, S., & Ahmadiasan, N. (2011). The long-term effects of resistance regular exercise on heart function and oxidative stress in rats. *Journal of Ardabil University of Medical Sciences, 12*(3), S264-256.

Rossow, L.M., Fahs, Ch.A., Sherk, V.D., Seo, D., & Bemben, D.A. (2011). The effect of acute blood-flow-restricted resistance exercise on postexercise blood pressure. *Clinical Physiology and Functional Imaging, 31*, 429-434.

Sagiv, M., Ben-Sira, D., & Goldhammer, E. (1999). Direct vs. indirect blood pressure measurement at peak anaerobic exercise. *International Journal of Sports Medicine, 20*(5), 275-8.

Sowmya, R., Maruthy, K.N., & Gupta, R. (2010). Cardiovascular autonomic responses to whole body isotonic exercise in normotensivehealthy young adult males with parental history of hypertension. *Indian Journal of Physiology and Pharmacology, 54*(1), 37-44.

Suga, T., Okita, K., & Morita, N. (2009). Intramuscular metabolism during low-intensity resistance exercise with blood flow restriction. *Journal of Appllied Physiology, 106*(4), 1119-1124.

Takano, H., Morita, T., Iida, H., Asada, K., Kato, M., Uno, K. .... &, Nakajima T. (2005). Hemodynamic and hormonal responses to a short-term low-intensity resistance exercise with the reduction of muscle blood flow. *European Journal of Applied Physiology, 95*, 65-73.

Takarada, Y., Sato, Y., & Ishii, N. (2002). Effects of resistance exercise combined with vascular occlusion on muscle function in athletes. *European Journal of Applied Physiology, 86,* 308-14.

Takarada, Y., Takazawa, H., Sato, Y., Takebayashi, S., Tanaka, Y., & Ishii, N. (2000). Effects of resistance exercise combined with moderate vascular occlusion on muscular function in humans. *Journal of Appllied Physiology, 88*(6), 2097-2106.

Wilmore, J.H., & Costill, D.L. (1994). Physiology of sport and exercise. Trans Moeini Z, Rahmaninia F. Rajabi H.AghaAli Nejad H. Salami F. Tehran: Mobtakeran. 148-167.

Yasuda, T., Ogasawara, R., Sakamaki, M., Ozaki, H., Sato, Y., & Abe, T. (2011). Combined effects of low-intensity blood flow restriction training and high-intensity resistance training on muscle strength and size. *European Journal of Applied Physiology, 111*, 2525-2533.